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HAS THE COVID-19 PANDEMIC FAVORED HOME BUYERS OR SELLERS?

Evidence from Helsinki housing markets based on skewness of residuals

Master's Thesis
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Abstract

This study examines whether the global COVID-19 pandemic has caused an imbalance between buyers and sellers in the Helsinki housing markets. House price formation is a process between the buyer and the seller, the end result of which is to achieve a price that is pleasant for both parties. In the event of imbalance, one of these parties will benefit from the market situation. Furthermore, the study assesses the effects of the pandemic on people's living conditions as well as housing preferences.

In the empirical part of the study, we build a model based on Rosen's (1974) theory of hedonic prices, after which we approach the main research question of the study through Pakarinen's (2018) dissertation methods by analyzing the skewness of residuals of the estimated regression models. In this case, we can analyze whether the actual transaction price of the apartment differs from the price of our modeling, which is estimated according to the characteristics of the apartment. Besides, it can be interpreted whether the market has favored buyers or sellers during the COVID-19 pandemic.

The study is limited to the Helsinki housing market and old apartment buildings. The research data was collected from the website Asuntojen.hintatiedot.fi and there are 4015 observations in our final data set. The transactions have taken place between 5/2019 and 12/2019 (pre-pandemic data) and 5/2020 – 12/2020 (pandemic data).

The study shows that during the COVID-19 pandemic, the Helsinki housing market has been significantly inefficient compared to the pre-pandemic period. 37.5 percent of pre-pandemic models are skewed, while the corresponding proportion in pandemic models is 62.5 percent. Before the pandemic, home sellers have had the opportunity to get a substantial overprice on their homes in 66 percent of the models. During the COVID-19 pandemic, the situation has been the opposite and in all models, homebuyers have had the opportunity to find apartments that are significantly cheaper than the median prices of the models. This can be partly explained by the fact that people's income levels declined with the onset of the pandemic due to unemployment and layoffs, leading to the forced sale of housing.

The contribution of the study is strong, as this study is the first to examine the effects of the COVID-19 pandemic on the efficiency of the Finnish housing market and the balance between buyers and sellers.

Keywords COVID-19, hedonic pricing method, housing markets, efficiency, Finnish real estate market

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Tiivistelmä

Tässä tutkimuksessa tutkitaan, onko globaali COVID-19 –pandemia aiheuttanut epätasapainoa ostajien ja myyjien välille Helsingin asuntomarkkinoilla. Asuntojen hintojen muodostuminen on prosessi ostajan ja myyjän välillä, jonka lopputuloksena pyritään saavuttamaan molempia osapuolia miellyttävä hinta. Epätasapainotilanteessa jompi kumpi näistä osapuolista hyötyy markkinatilanteesta. Lisäksi tutkimuksessa arvioidaan pandemian vaikutuksia ihmisten asuinolosuhteisiin sekä asumisen preferensseihin.

Tutkimuksen empiirisessä osassa rakennamme Rosenin (1974) hedonisten hintojen teorian pohjalta mallin, jonka jälkeen lähestymme tutkimuksen päätutkimuskysymystä Pakarisen (2018) väitöskirjan metodien kautta analysoimalla estimoitujen regressiomallien residuaalien vinouksia. Tällöin voimme analysoida, poikkeaako asunnon todellinen transaktiohinta mallinnuksemme hinnasta, joka on estimoitu asunnon ominaisuuksien mukaan. Lisäksi voidaan tulkita, ovatko markkinat suosineet ostajia vai myyjiä COVID-19 –pandemian aikana.

Tutkimus on rajattu Helsingin asuntomarkkinoille sekä vanhoihin kerrostaloasuntoihin. Tutkimuksen aineisto kerättiin Asuntojen.hintatiedot.fi sivustolta ja lopullisessa aineistossamme on 4015 havaintoa. Transaktiot ovat tapahtuneet aikavälillä 5/2019 – 12/2019 (ennen pandemiaa kuvaava aineisto) sekä 5/2020 – 12/2020 (pandemia-aineisto).

Tutkimus osoittaa, että COVID-19 pandemian aikana Helsingin asuntomarkkinat ovat olleet huomattavan epätehokkaat verrattuna pandemiaa edeltävään aikaan. 37.5 prosenttia ennen pandemiaa kuvaavista malleista ovat vinoutuneita, kun taas pandemiamalleissa vastaava osuus on 62.5 prosenttia. Ennen pandemiaa asunnon myyjillä on ollut tilaisuus saada asunnoistaan huomattavaakin ylihintaa 66 prosentissa malleista. COVID-19 -pandemian aikana tilanne on ollut päinvastainen ja kaikissa malleista asunnon ostajilla on ollut tilaisuus löytää huomattavasti mallien mediaanihintoja edullisempia asuntoja. Tämä voidaan osittain selittää sillä, että ihmisten tulotaso heikentyi pandemian alkaessa työttömyyden ja lomautusten myötä johtaen siihen, että asunnoista on ollut pakko luopua.

Tutkimuksen kontribuutio on vahva, sillä tämä tutkimus on ensimmäinen, joka tutkii COVID-19 -pandemian vaikutuksia Suomen asuntomarkkinoiden tehokkuuteen sekä ostajien ja myyjien väliseen tasapainoon.

Avainsanat COVID-19, hedoninen hinnoittelumalli, asuntomarkkinat, tehokkuus, Suomen asuntomarkkinat

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1 Introduction

In early 2020, people's lives underwent a major change as the COVID-19 epidemic spread around the world. The virus is highly contagious and very lethal, especially for high-risk groups, so people's lives have had to be restricted a lot. In many countries, people have had to adapt to social distancing and to the fact that restaurants, clubs, or museums, for instance, cannot be visited as before. Although life in China has returned to near normal in early 2021 and reported infections at the source of the pandemic have greatly diminished, the epidemic is still rampant in the rest of the world. Millions of infections globally and tens of thousands of deaths are still reported weekly. Besides, new, more contagious virus variants have been reported in, for example, the United Kingdom, South Africa, India, and Brazil, causing additional concern. However, there is hope that vaccine programs are advancing at a relatively rapid pace and several vaccines against the virus have already been developed which have been shown to work (WHO, 2021).

This research focuses on evaluating the housing market in Helsinki, the capital city of Finland, before and during the COVID-19 outbreak. Measured in terms of the number of contagions, Finland has survived well compared to other European countries, for example through timely restrictions. However, strict restrictions and an uncertain future have another side, which is reflected in the economic downturn. In the wake of the pandemic, a historic number of layoffs were experienced in Finland, affecting about 200 000 people (Brotherus, 2020a). Housing prices are expected to react when homes do not go on sale within the desired time or people are forced to sell their homes. On the other hand, low-interest rates and deferred amortizations have so far protected against this. At the same time, purchasing power has remained high. Due to this and the low interest rates, inter alia, demand for housing has remained strong, especially in the Helsinki metropolitan area.

The effects of the COVID-19 pandemic on the economy are clear, as shown, and the housing market interacts closely with different sectors of the economy. Housing has a significant impact on the national economy and individual households: housing and its related items form the largest single part of Finland's gross domestic product. All people need a roof over their heads, and that is why housing is one of the largest items of expenditure in households. Besides, housing wealth is also the largest form of household wealth. Housing differs in many ways from other forms of wealth, as it is also a consumable commodity

(Laakso, 2000; Oikarinen, 2011). The fluctuation in house prices and its impact on household wealth has been extensively studied (e.g. Cristina & Sevilla, 2013; Oikarinen, 2011; Favilukis, Ludvigson & Nieuwerburgh, 2013; Aladangady, 2017; Campbell & Cocco, 2007). Housing can perform many distinct functions concurrently like consumption, store of wealth, being a long-term investment, and act as security collateral. For this reason, many previous economic crises, such as the recession of the 1990s and the subprime crisis of 2008, have been strongly tied to the housing market. Consequently, this emphasizes the close link between the country's financial and macroeconomic stability and real estate price dynamics (IMF, 2019).

There has been a great deal of speculation, but very limited evidence, about the effects of the coronavirus pandemic on the Finnish housing market. This study seeks to fill this gap in the Helsinki housing market. The study is limited to Helsinki apartment buildings, excluding new residential buildings. The Finnish housing market has been dominated by urbanization in recent decades, which has accelerated steadily. People are moving from the countryside to growth centers that offer jobs and better services, as well as educational opportunities (Oikarinen, 2007: 62, OSF 2020). In the Finnish market, urbanization has been studied especially by Loikkanen & Laakso (e.g. 2013 & 2016). The research is limited to the Helsinki housing market due to the heterogeneity of the area and the significantly higher price level compared to the rest of the country. Besides, Helsinki has had the highest number of infections in Finland. Housing prices in the metropolitan area have been rising steadily, which has sparked debate even about a possible housing bubble and this phenomenon has been studied by Oikarinen (2005), for example. This research seeks to determine whether the coronavirus has had a significant impact on the situation.

1.1 Research questions & contribution of study

The formation of the sale price of an apartment is a process between the buyer and the seller, in which the aim is to reach a price that is pleasant for both parties. The main purpose of this study is to determine whether the coronavirus situation has caused imbalances in the Helsinki housing market. In these circumstances, one of the parties, the buyer or the seller, would benefit from the market situation.

Research question:

Has the COVID-19 pandemic favored either buyers or sellers in the Helsinki housing market?

People living in urban areas, especially in Helsinki, are certainly aware that dwellings with similar physical characteristics may not be as expensive in another city or district. Apartments can be completely differently priced in different parts of the city, as people buy an apartment based on many different factors and the choice is not made based solely on the number of walls and rooms (Laakso, 1997). Some may appreciate the fact that the apartment has a beautiful sea view and is located on the top floor, while for others it may be important that the schools are close by and the apartment has a great courtyard. There has been a lot of discussion in the media that the coronavirus has affected living conditions and needs in Finland. This may be reflected in the fact that apartments today are required to have different features or characteristics than before, which is approached in sub-research question.

Sub-research question:

Do buyers in the Helsinki housing market value different housing characteristics and living conditions than before the COVID-19 pandemic?

This study has a strong contribution to previous literature. Hedonic pricing models in the Helsinki housing market have previously been utilized by, among others, Pakarinen (2018), Laakso (1992; 1997), Vainio (1995) & Hiironen et al. (2015). This paper reveals fresh evidence on how hedonic pricing models perform in the Helsinki housing market.

The actual effects of the COVID-19 pandemic on the Helsinki housing market bargaining process have not been studied in the past in the academic literature, so the study has a very strong novelty value. There has been a lot of speculation as to whether it has been favorable to sell or buy an apartment during the pandemic. However, there is very limited real evidence of the situation, which is complemented by this study. In addition to the academic literature, the findings of the study are useful for financial institutions researching the housing market and housing investors, among others. Almost every person buys their own home at some point in their lives, and for many, this process is ongoing during the coronavirus pandemic, so research aims to bring information to ordinary home buyers as well to support decision-making. In general, the effects of pandemics on the housing markets have been studied relatively little globally in the academic literature, and this study fills the gap by serving as the first study of the Finnish and Helsinki housing markets.

1.2 Research approach

This is a quantitative study based on transaction data extracted from the Asuntojen.hintatiedot.fi website. Two separate data sets have been collected for the study, which are from the periods 5/2019 – 12/2019 (prior to the corona pandemic data) and 5/2020 – 12/2020 (the corona pandemic data). The study utilizes a hedonic pricing model and the econometric modeling is performed using the linear ordinary least squares (OLS) method. A hedonic pricing model is a method in which separate prices can be derived for each feature of a commodity. In the context of dwellings, the hedonic function includes the local, structural, and residential foundations of the dwelling.

The research approach is implemented following the same methods as Pakarinen (2018) in his doctoral dissertation. This study seeks to measure the functioning of the housing market during the corona pandemic by finding evidence of abnormality by which we mean residual skewness in this context. The asymmetry of the distribution shows that the market is inefficient and either sellers or buyers have an advantage over other market participants (Pakarinen, 2018). The skewness of residuals will be modeled by apartment type: studios, two-room apartments, three-room apartments and apartments with more than three rooms.

In hedonic price functions theory, individual features of an apartment cannot be sold separately. Instead, the apartments with all their features are sold as a single unit at a certain market price. The basic idea is that the market indirectly reveals a hedonic price function that links features together. Within the framework of this theory, it is possible to derive an indirect price for each characteristic of housing. Consequently, the supply and demand of different features can be compared (Laakso, 1997). In this study, the sub-research question is approached by both on the basis of the research literature and comparing the hedonic regression models and analyzing whether there are discrepancies between the characteristics before and after the corona pandemic.

1.3 Structure of the study

This study consists of six main chapters. The following chapter presents the main literature behind the study, which focuses on housing as an investment class and its specific characteristics, the Finnish housing market, and the effects of the COVID-19 pandemic on the housing market at the global level. In addition, we present a few studies of the Helsinki housing market that have utilized the same methods as in this paper.

The third chapter of the study presents the theory of hedonic prices as the basis of the empirical contribution. The actual empirical part begins in the fourth chapter, which presents the research data, and in this chapter, we also make a descriptive analysis of the effects of the COVID-19 pandemic on the Helsinki and Finnish housing markets to support the analysis of the results. In the fifth chapter, we present the results and findings of our study. In the last chapter, we focus on a deeper analysis of these results, in which we seek to answer the research questions in our research and draw conclusions. Moreover, in this section, we present the limitations of the research and consider possible topics for further research.

2 Literature review

This chapter introduces dwellings as an investment class in more depth and introduces how they differ from other investment instruments. Also, the section explains the special features of the housing market and especially the development of the Helsinki housing market to date. Besides, we present studies that have utilized hedonic pricing models in the Helsinki housing market and based on which this study is also built.

Finally, the chapter focuses on presenting key academic research related to the impact of pandemics on the housing market, especially for COVID-19 at the global level. There is no academic literature on the Finnish market on the effects of pandemics on the housing market. Research related to the corona pandemic and housing markets around the world is presented to gain a holistic understanding of the global impact on the housing market and thus compare the results with data from the Helsinki market. Research utilizing hedonic pricing models, on the other hand, is useful especially when addressing the sub-research issue of this study.

2.1 Dwelling as an investment and its special features

For most of us, a dwelling is a must-have commodity, the home where we spend much of our lives. On the other hand, housing is also a very important asset class, as it provides a stable cash flow and hedges against inflation in the long run. Although this study focuses on ordinary housing and dwellings, it is good to note that real estate is a rather broad term and is easily confused to refer only to residential real estate. In addition to dwellings, real estate can be roughly divided into business premises owned by companies and the public sector. On the other hand, legally real estate refers to land and buildings located in this area (Olkkonen, Kaleva & Land, 1997: 11). Instead, real estate investment can be concentrated on the acquisition of real estate or shares entitled to it. This means buying or renting out housing, industrial and office space, or even forest land. Real estate investments have to compete for capital with other forms of investment, and this has become increasingly important as the financial markets have liberalized (Kallunki, Martikainen & Niemelä, 2007: 115).

In their study, Hudson-Wilson, Gordon, Fabozzi, Anson, and Giliberto (2003) state that direct real estate investments, like dwellings, are often seen as steady cash flow investments in the form of rental cash flow and appreciation, and that real estate returns provide significant diversification benefits over other asset classes. Berges (2004: 15-18) confirms that investing in housing is suitable for both long-term and short-term investment, but is typical of long-term investment due to high transaction costs. An apartment is often bought with debt, according to Oikarinen (2007: 108), about 90% of household debt in Finland is a loan for housing.

Housing has certain characteristics that distinguish it from other financial assets. Oikarinen (2007: 33) mentions in particular heterogeneity, indivisibility, and large unit size. Financial markets trade assets that can be very similar and homogeneous. On the other hand, two separate dwellings are never exactly the same, as the dwellings may be located in different places, be of different sizes or, for example, of different ages. The unit size of real estate assets is typically large, the transaction takes a long time to complete and the transaction costs are high. Thus, the liquidity of direct real estate investment is weak compared to other forms of investment. Besides, the single dwelling often has to be acquired as a whole and often for quite a long time, and it is not easily possible to divide its ownership (Kallunki et al. 2007: 116; Oikarinen, 2007; 33). In addition to these, Arnott (1987: 960) mentions a few typical features of housing as a commodity:

Table 1: Housing features

Durability	Housing is a sustainable commodity.
Importance	One of the most important investments of an individual during a lifetime.
Necessity	Satisfying a basic human need to act as a shelter.
Spatial fixity	The location of the dwelling cannot be changed easily or cost-effectively.
Inflexibility in production	Construction is slow, making it difficult to respond quickly to demand.
Information asymmetry	Market participants may have different amount of information related to dwelling characteristics.

The latter feature is the one that is most relevant to this study when we examine the asymmetries of market participants. Asymmetries in the housing market are discussed in more detail in Section 2.2 below.

2.2 Special features of housing market

The housing market is very extraordinary compared to other markets. As in the market in general, housing prices are determined by supply and demand (Laakso & Loikkanen 2004: 250-251). However, there is no public stock exchange for homes, such as stocks. Due to the heterogeneity of housing and the lack of a market, there are strong asymmetries in the housing market. A home buyer often has a lot of work to do to get relevant information about a dwelling's features or neighborhood. Even if the buyer of the apartment spends a lot of time gathering information, there is still always an asymmetry between the buyer and the seller (Oikarinen 2007: 34). The asymmetry of the housing market has been studied quite extensively in the academic literature, such as Wong, Yiu & Chau (2012); Zhou, Gibler & Zahirovic-Herbert (2014) and Qiu, Tu & Zhao (2020).

The supply of housing is fixed in the short term and the supply consists of the existing building stock. The housing stock can be increased through new production. Instead, the housing stock decreases through deconstruction (Kivistö, 2012). However, new production is slowly affecting the housing stock, which causes counter-cyclicality in the housing market, in other words supply reacts to changes in demand with a delay (Case & Shiller, 1989).

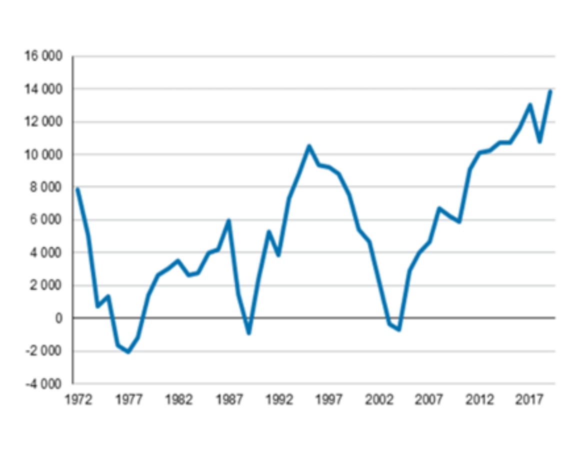
The housing market ideally offers several housing options for consumers in different life situations. Consumers' willingness to pay for apartments and their various characteristics is influenced by consumer preferences and how much money a consumer has at his disposal. In practice, not all consumers will find an ideal home in the housing market with a combination of features, but trade-offs will have to be made that are affected by disposable income. It can be stated that demand at least partly describes the choices made by the home buyer within the resources provided by the financial markets as well as his own financial resources (Siikanen & Tyrkkö, 1993). In Helsinki, this has been reflected, for example, in the demand for small apartments. People appreciate the good location, which in turn is reflected in the higher price per square meter of the apartment. In this case, a compromise must be made within the framework of financial resources for the acquisition of a smaller apartment.

Siikanen et al. (1993) state that when referring to the housing market, it actually refers to several different types of sub-markets. These include owner-occupied and rental housing, as well as non-subsidized and publicly supported housing construction. Also, we can talk about the sub-market for old housing and new production. Traditionally, the market is divided into owner-occupied and rental apartments. This paper focuses on owner-occupied housing, as the rental housing market is very different in its characteristics. The market can also be divided by type of building and even type of dwelling, and this study focuses on apartment buildings and their different types of dwellings, like studios and two-room apartments.

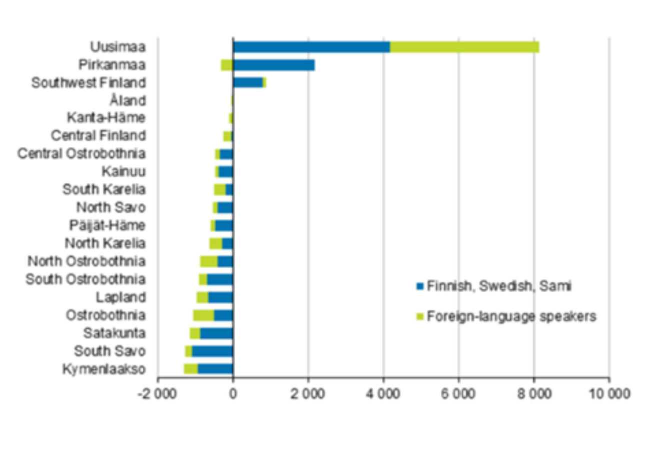
According to Loikkanen (2013), the housing market is also divided regionally. The housing market is regional, as the housing market in each region has its specific characteristics. The research area must be a unified housing market area for the interpretation of the results to be meaningful. This work focuses on the Helsinki housing market and its sub-regions, which we will focus more on Sections 2.3 and 4.2.2.

2.3 Overview of Helsinki and Finnish housing markets

Urbanization and the associated concentration of production and population is one of the most significant changes at the societal level worldwide. The phenomenon has had a very strong effect in Finland throughout the post-war period and the change is continuing at an accelerating pace. People are moving to growth centers in rural areas and the rural population is being reduced at the same time as aging and thus increasing mortality. Over the last thirty years, the strongest population and employment growth have been concentrated in the Helsinki region and six other large urban areas where university-level education is available. Growth areas are university cities that, together with their surrounding municipalities, form a labor and housing market area. They have been attractive to both businesses and households (Loikkanen et al. 2016).



a) Total net migration in Greater Helsinki in 1972 to 2019 (OSF, 2020a).



b) Migration gain for regions by language 2019 (OSF, 2019).

Figure 1. Migration statistics in Helsinki and Finland.

In 2019, net migration to the municipalities of the Helsinki metropolitan area was the highest in 50 years. Total net migration includes migration gains from other parts of Finland and abroad, and the share of foreign speakers was very significant, 71 percent (OSF, 2020a). This is highlighted in Figure 1.

Finland's regional structure is changing at a fast pace: population growth in the metropolitan area and decrease in rural areas are directly reflected in the housing market. Rapid urbanization is the most obvious driving force behind the development of the housing market. Housing sales are brisk and prices are increasing strongly in areas with growing populations. However, there are fewer and fewer such cities in Finland, and the problems in the housing market are increasingly reaching medium-sized cities and especially remote areas, where the prices are falling. In the housing market of growth centers, demand is growing and new homes are being built rapidly. At the same time, cities are condensing and housing prices are rising (Keskinen, Karikallio & Kiviholma, 2020). The figure of Kokkonen, Korhonen, Rämö and Vuorio (2020) shows the price development of different cities.

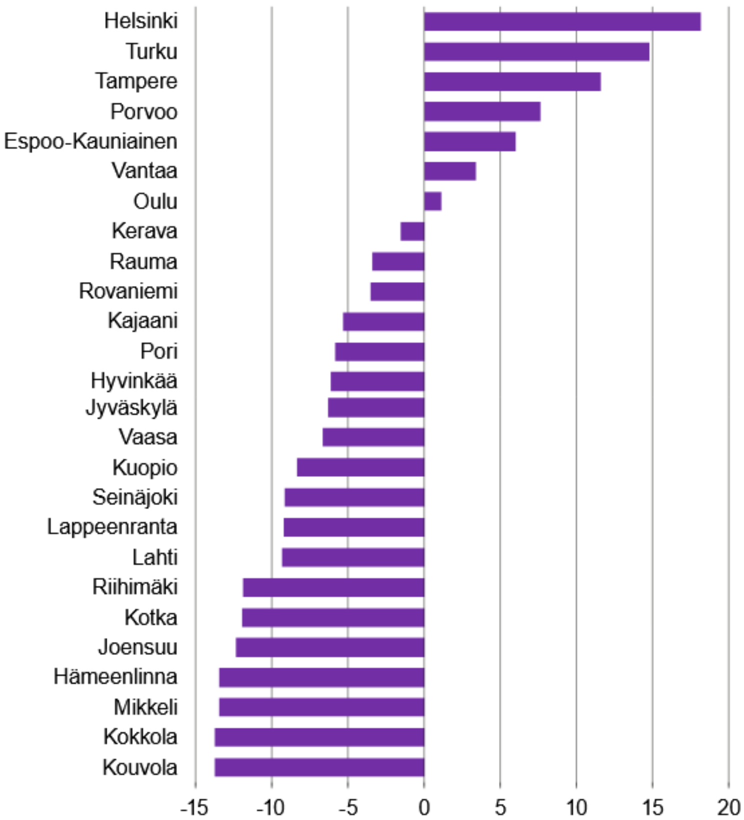
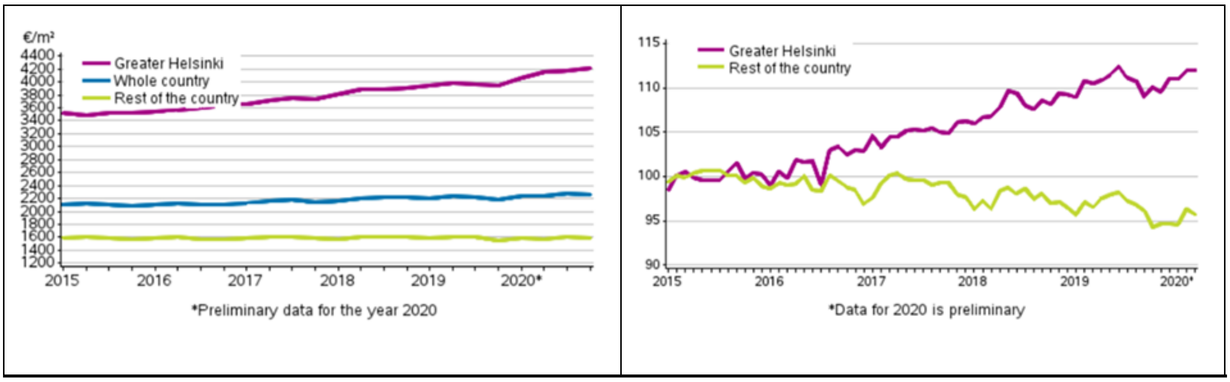


Figure 2. Price development of old owner-occupied housing in the largest cities and provincial centres in early 2020 compared to 2015.

Source: Kokkonen et al. (2020)

The Helsinki housing market has been characterized by a very rapid rise in prices compared to the rest of the country, which is also shown in Figure 2. For example, in 2019, house prices in Helsinki rose by about 3.4 percent, compared with 1.2 percent in the whole country (Keskinen et al. 2020). Naturally, Helsinki is also very dominant in terms of prices per square meter compared to the rest of Finland. In January 2021, the average price per square meter in Helsinki was 4 561 euros, while it was elsewhere in Finland at 1 667 euros (OSF, 2021a). There are also large differences in prices per square meter within regions. In the center of Helsinki, the average square meter of a two-room apartment costs almost 8 000 euros (Kokkonen et al. 2020).



a) Average prices per square meter of dwellings in old blocks of flats (OSF, 2020b).

b) Development of prices of old dwellings in housing companies by month (OSF, 2021a).

Figure 3. Development of prices of old dwellings in Finland.

In addition to urbanization, there are other explanatory factors for the rise in house prices in growth centers. Keskinen & Brotherus (2021) highlight the low level of mortgage rates in particular. Euribor rates, such as the 12-month Euribor, which often serves as a reference rate for mortgages, started to fall again during the pandemic and have increased the enthusiasm to buy a home. Besides, banks have intensified competition, which has reduced loan margins to very low levels.

Keskinen et al. (2020) state that the price development of dwellings has also differed in terms of the number of rooms in the dwelling. In growth centers, studio apartment prices have risen significantly faster than for other types of housing. The increase in the need for small dwellings is explained, among other things, by a large number of young people in the Helsinki metropolitan area and the increase in single living, but also by the aging of the population when it is easier to live in smaller dwellings. Also, the need for small dwellings increases as the size of households decreases. The growth of single-person households is illustrated in Figure 4 (OSF, 2019b).

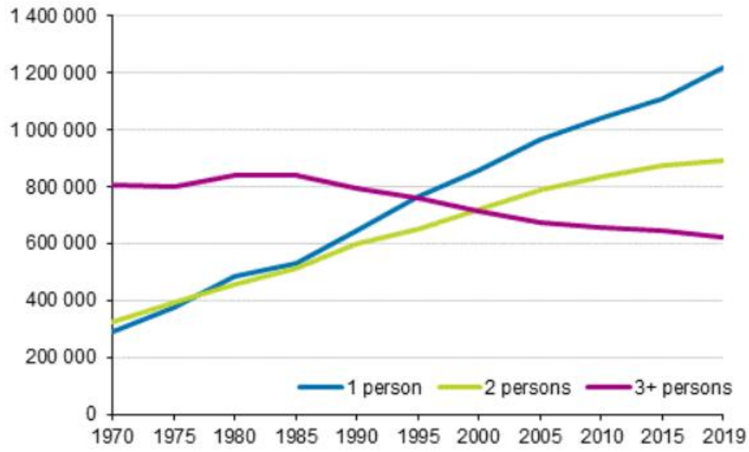


Figure 4. Number of household-dwelling units by size in 1970–2019.

Source: OSF, 2019b

Investors are interested in smaller homes in key locations as these offer a stable return during low interest rates. Instead of first-time buyers, a significant part of small apartments in the Helsinki area as well as in other growth centers end up in the ownership of investors, and rising prices increase demand in the rental housing market (Keskinen et al. 2020).

2.3.1 Research on Helsinki housing markets using hedonic price functions

By far the most relevant research for this study is Sami Pakarinen's (2018) dissertation. In his dissertation, Pakarinen (2018) examines whether there is an imbalance between buyers and sellers in the Helsinki housing market (whether the market favors either party) and possibly inefficiency. The dissertation utilizes the Asuntojen.hintatiedot.fi database, which is also used in this paper. The material includes all block of flats transactions completed in Helsinki in 2011-2012, excluding new apartments.

In Pakarinen's (2018) study, the hedonic price function is estimated using both OLS regression and semiparametric CNLS regression, which is found to work better than the parametric estimate. In addition, the estimation utilizes the StoNED method, which is originally presented by Kuosmanen & Kortelainen (2012). As a result of the study, inefficiencies occur in the Helsinki housing market, varying between 4 and 13 percent between different sub-markets. On average, the market is 92% efficient. In the case of an individual transaction, the inefficiency is on average 18 400 euros and the results show that buyers benefit more on average in the Helsinki housing market than sellers, but in some market areas sellers also have strength over buyers. On average, buyers benefit from a surplus of 5 900 € per housing sale. As an interesting detail, buyers seem to benefit more from larger apartments, while for smaller ones, sellers have more bargaining power.

As in this paper, Pakarinen (2018) examines the skewness of the residuals of his hedonic regression models when assessing whether the Helsinki housing market is inefficient. Asymmetry in the distributions of residuals indicates inefficiency. In this context, the positive skewness indicates the market favoring buyers and the negative favoring sellers on aggregate level. Pakarinen's (2018: 86) results on the skewness of the residuals are presented in the table below, in which the transactions are divided by apartment type and area, with Helsinki-1 being the downtown area.

Table 2: Distribution statistics of regression residuals

Number of rooms	Region	Std. Dev.	Min	Max	Skewness	Kurtosis
Single room	Helsinki-1	0.07	-0.19	0.27	0.21	1.70
	Helsinki-2	0.09	-0.50	0.20	-0.86	2.48
	Helsinki-3	0.07	-0.21	0.22	-0.11	1.05
	Helsinki-4	0.05	-0.14	0.14	-0.35	2.05
Two rooms	Helsinki-1	0.11	-0.30	0.43	0.77	2.04
	Helsinki-2	0.10	-0.39	0.34	-0.22	0.62
	Helsinki-3	0.10	-0.29	0.59	0.49	3.64
	Helsinki-4	0.08	-0.25	0.21	-0.21	0.08
Three or more rooms	Helsinki-1	0.12	-0.35	0.42	0.31	1.12
	Helsinki-2	0.11	-0.36	0.56	0.02	2.16
	Helsinki-3	0.11	-0.33	0.45	0.37	1.56
	Helsinki-4	0.10	-0.35	0.53	0.14	2.90

Source: Pakarinen, 2018: 86

Pakarinen's (2018) study shows that the Helsinki housing market has been favorable for sellers in the case of studio apartments, while buyers have had more bargaining power in the case of larger apartments. However, these results are interpreted on aggregate level. In the case of strong negative skewness, buyers have been offered individual apartments significantly lower than the median price, while in the case of strong positive skewness, there has been little supply of very significantly underpriced dwellings. This paper will show whether the COVID-19 pandemic has caused changes in the market situation.

Laakso (1997) studies the demand for various housing characteristics in the Helsinki metropolitan housing market, utilizing the theory of hedonic prices. The data are from 1993 for housing sales, with a total of about 17 300 transactions. The data include solely condominiums, concluding that detached houses are excluded from the research. The results show that the spaciousness of living has a very large effect on the price, so semi-detached houses are more expensive (about 15 %) than apartment buildings of the same size, taking into account local factors.

The age of the dwellings decreases prices up to about 50-60 years, but after that the price increases as the age increases. This is not explained solely by the fact that the location of old dwellings is better, as the effect of local factors has been taken into account in the study. Apartments on an own plot are about 10% more expensive than those on a rented plot. Furthermore, the proximity to the sea has a very large positive effect on the price and such apartments are about 25-50% more expensive than those more than a kilometer from the shore. The proximity of the railway station raises the price at its highest by about 4-6%. The study also highlights the effect of the Helsinki metro on prices, which in this case means the Eastern metro from Mellunmäki station to Ruoholahti. After the introduction of the metro, house prices rose by as much as 8-10% as the distance to the city center decreased. At the same time, rents rose, whereupon some of the investment spent on the subway passed on to homeowners (Laakso, 1997).

The proximity of power plants and the location in the aircraft noise area will lower house prices by almost the same amount, by about 2-5%. Besides, Laakso (1997) models the social status of regions in the study, for which variables on the demographic, social, and economic status of the population have been constructed using principal component analysis. In terms of the social status of the residential area, the apartments in the top quarter are about 25% more expensive than those in the bottom quarter. Furthermore, dwellings in the vicinity of a good level of service are 10% more expensive than similar types of dwellings in the vicinity of a low level of service. However, the proximity of the apartment to the center of Helsinki has the most significant effect, and apartments with a 10-minute traffic distance are about 50% more expensive than similar apartments that are further away. However, the price peak is not right in the city center, which may be due to traffic noise, congestion or crime level, for example, but about 10 minutes away (Laakso, 1997).

Vainio (1995) studies the externalities affecting housing in his dissertation. Externality means that human consumption or manufacturing processes have positive or negative externalities to the well-being of others. The study deals with the distribution of the adverse effects of air pollution and traffic noise and the assessment of the financial disadvantages of the nuisances using hedonic pricing models. The research has been conducted in the Helsinki housing market. The information provided by hedonic attributes as part of Vainio's (1995) research is very important, as the paper examines two completely similar dwellings, one in a congested and noisy place and the other in a quiet location.

Vainio (1995) uses very precise apartment-specific factors in the paper, such as the direction of the windows and their thickness. Noise is measured using the decibel level of cars passing a street near the apartment during the day and air quality is assessed based on data produced by Helsinki air measuring stations, so this information is not street-specific in the study. Research shows that households pay a productive noise of about thousand cars annually, with a limit of 55 decibels. Also, the hedonic pricing model of the study shows that air pollution has an insignificant and often even positive effect on house prices. Vainio (1995) suspects the reason for the lack of data, as street-specific information on air quality is missing. It is also possible that the questionnaire on which the study was based has been answered dishonestly. As an interesting details for this study, Vainio (1995) points out that an elevator often has a negative effect on the price of an apartment, regardless of the number of floors, while a sauna increases the price of an apartment by about 5%.

Hiironen et al. (2015) provide more up-to-date information on the effects of the new metro line on housing prices in the Helsinki metropolitan area using hedonic pricing models and OLS method. The case area in the study is Matinkylä in Espoo. The study shows that the metro station has a positive effect on housing prices within a radius of 0-800 meters. Within a radius of 0 to 400 meters, the effect is 15 percent, while within a radius of 0 to 800 meters, 11 percent.

Kortelainen & Saarimaa (2015) study the effects of owner-occupied housing on the price level of the neighborhood in the Helsinki housing market, utilizing hedonic price theory and semi-parametric models. There are tax benefits associated with owner-occupied housing that is justified by its positive externalities. Such an external effect is, for example, that the homeowner benefits from a comfortable living environment and local services as the value of her home increases. Because of this, she is likely to seek to promote the comfort of the living environment for her benefit. However, the study does not find such significant, positive externalities for owner-occupied housing, in which case owner-occupied housing and rented housing should be treated more equally.

On the basis of Laakso's (1997) and Vainio's (1995) studies, some further research has been carried out later in the Helsinki housing market using hedonic pricing models, such as the theses of Huttunen (2009) and Brotherus (2011).

2.3.2 Crisis on the Finnish housing markets

By far the biggest blow to the housing market so far has been the recession of the 1990s, preceded by the housing bubble of 1987-1989, when house prices rose by as much as 60% in two years. This was due to deregulation and liberalized lending, with house prices rising significantly faster than disposable income. Housing prices did not start to rise more permanently until 1996, and normal trade volumes were reached in 1998, so the effect lasted for about ten years. Despite the collapse in trade volumes in 1989, prices rose by more than 20 percent. However, between 1990 and 1993, prices fell by about 40% due to the compulsory sale of dwellings. This was the result of insufficient collateral for mortgages, which exceeded the market value of the home. In addition, mortgage rates were very high, at around 15 percent, and banks were in difficulty and could not wait for a possible rise in house prices. (Oikarinen, 2007: 60; Kivistö, 2012 & Lehtinen, 2020). The trading volumes are illustrated in more detail in Table 3 below (Lehtinen, 2020).

Table 3: Trade volume and price index of old dwellings in Finland during the recession of the 1990s

	Apartments sold	Annual change %	1988=100	Annual change %
1988	87 392		100	
1989	60 738	-30,5	122,3	22,3
1990	47 496	-21,8	116	-5,2
1991	52 469	10,5	99,7	-14
1992	59 639	13,7	81,9	-17,8
1993	68 901	15,5	75,7	-7,6
1994	65 147	-5,4	80,2	5,9
1995	60 983	-6,4	77	-3,9
1996	75 647	24	81,5	5,9
1997	72 888	-3,6	96,1	17,9
1998	76 835	5,4	105,9	10,2

In the autumn of 2008, the international financial markets plunged into a crisis, the effects of which quickly spread around the world economy, and the Finnish economy also ended in recession. According to Lehtinen (2020), the sale of old dwellings decreased by more than 40 percent from the second quarter of 2008 to the end of the year, so that the decline for the whole year was 14 percent. However, the market started to recover immediately in early 2009 and normal trade volumes were already reached in 2010. Housing prices eventually fell by about 5 percent from the end of 2008 and the situation improved immediately at the beginning of 2009. The exceptionally tight monetary policy of the

European Central Bank (ECB) eased household debt service costs, which was particularly reflected in the housing market. Housing prices did not fall significantly, which had a sustaining effect on households' net worth. The low interest rate level particularly affected the Finnish market, where short-term reference interest rates, such as 3-month and 12-month Euribor interest rates, serve as mortgage interest rates, while at the global level reference rates can be up to 5-10 years (Prime Minister's Office of Finland, 2011).

In addition to these, the European debt crisis, which began immediately after the financial crisis with the collapse of the Greek economy, has had an impact on the Finnish housing market until 2020. The sales volumes of old dwellings decreased by about 24 percent from 2011 to 2014, although housing prices were hardly affected by the crisis (Lehtinen, 2020). The European Union has sought to increase macroeconomic stability in the euro area, and national financial institutions thus have the right to strictly limit bank lending and household indebtedness if necessary (Pakarinen, 2018: 28). The effects of the financial crisis and the European debt crisis on housing sales in Finland are illustrated in Table 4 (Lehtinen, 2020).

Table 4: Trade volume and price index of old dwellings in Finland during the financial crisis and European debt crisis

	Apartments sold	Annual change %	1988=100	Annual change %
2007	97 251	2,1	183,2	5,5
2008	83 721	-13,9	184,7	0,8
2009	83 847	0,2	185,2	0,3
2010	93 309	11,3	202	9,1
2012	90 469	-3,2	212,3	1,9
2013	78 780	-12,9	216,9	2,2
2014	71 378	-9,4	216,2	-0,3
2015	77 207	8,2	215,4	-0,4

2.4 Impact of pandemics & COVID-19 on the housing markets globally

The impact of health emergencies or pandemics on the housing market is, overall, a much unexplored topic in the international literature. Reliable demonstration of the impact of a housing market shock like a pandemic is a challenging task. There have been quite rarely large-scale pandemics or epidemics in history, and there is little reliable information about them. It is particularly challenging to show the real consequences of the pandemic and the housing market.

Francke and Korevaar (2021) provide fresh, albeit historical, research data on the effects of pandemics on the housing market. They studied the effects of ten plague epidemics in the 16th and 17th centuries on the housing market in Amsterdam. The research also includes the effects of two 19th-century cholera epidemics in Paris. Some of these plague epidemics killed up to 10% of Amsterdam's population and about 2% of Parisians died in both cholera epidemics. According to research, these major epidemics caused a significant drop in house prices of about 10 % during the cholera epidemics and 13 % during the plague epidemics. However, despite high mortality, the price level did not collapse completely. The price shock came quickly: prices fell during the first half-year epidemic outbreak, but not much after that.

After the epidemic, the rise in house prices returned to its previous level relatively quickly. The return of price levels to the pre-pandemic situation is not included in the paper. The analysis of price developments does not suggest that the negative price impact of the epidemic has been offset by extraordinary price increase and the prices thus appear to have remained on a slightly lower level. Besides, Francke et al. (2021) show a smaller drop in rents than in prices. This reflects the rigidity and sluggishness of rental levels relative to house prices.

Wong (2008) analyzes the impact of the first pandemic of the 21st century, SARS, on housing prices in Hong Kong, which was severely affected by the epidemic. The observed price drop caused by SARS was less than two percent (1,6 %) at the entire city level. Besides, prices fell by 1 to 3 percent in residential buildings known to have SARS patients. During the pandemic, the local newspapers reported SARS cases at the building level. Compared to the findings of Francke et al. (2021), the price drop was small. This is due, among other things, to the lower mortality of the SARS epidemic and temporal and regional differences. Wong (2008) also states that several sellers seem to have postponed the sale of the apartment to a later date, which is in connection with the Amsterdam epidemics where a 25% drop in sales volumes is observed.

Wong's (2008) research is applicable to modern times in many ways. During the SARS epidemic, schools in Hong Kong were closed and other significant restrictive measures were taken for three weeks. On the other hand, SARS was significantly smaller in scale than the corona pandemic. Hong Kong was the worst affected region, but even there only 2.6 % of the population contracted the disease, and worldwide deaths remained marginal for SARS relative to the coronavirus.

Qian, Qiu & Zhang (2020) investigate the effects of the coronavirus on the Chinese housing market at the community level using the difference-in-difference method. The research data is in two parts. The first is data on residential communities with confirmed COVID-19 cases. The study selects the nearest community without confirmed cases as the control group for each of the communities with confirmed infections. The second data is the monthly average house price for each community with confirmed COVID-19 cases and the nearest community without cases. Three shocks are selected for the study before and after the outbreak of the coronavirus from October 2019 to April 2020. The sample of the study includes 18 466 findings, with 1 319 communities as a treatment group and 1 319 communities as a control group in 90 cities.

The results of the study show that when there are confirmed cases of COVID-19 in the community, housing prices fall by 2.47 % and the negative effects can continue for three months. The impact of COVID-19 on housing prices is greater than the impact of SARS, which is 1.6 %, as shown by Wong (2008), but less than the plague and cholera, which are 13 % and 10 % a year, respectively, as Francke et al. (2020) indicate. Furthermore, the heterogeneity analysis presented in this article shows that the negative impact of COVID-19 on housing prices is only in areas with higher levels of COVID-19 infection and poorer treatment conditions.

Huang, Pang & Wang (2020) study the effects of the corona pandemic on the price level of the Chinese housing market using hedonic regressions. The study was conducted between the 1st of January, 2019 and 31st of May, 2020. Cities with at least 1000 transactions during the period are included in the study, and the analysis results in 64 different cities and more than 700 000 transactions. Chinese New Year time was not taken into account in the study because people are on holiday at that time and there are almost non-existent numbers of housing transactions even during the normal pre-pandemic period.

The paper shows that the COVID-19 pandemic affects negatively housing prices and sales volumes in the Chinese housing market. The negative impact on transaction volume is much greater than the impact on housing prices. House prices fell by about two percent in the four weeks after the outbreak, and house prices did not return to 2019 levels by the end of May. The decline in prices is thus fairly in line with the findings of Qian et al. (2020). The study also shows that confirmed cases of infection in the city significantly reduce the price of housing and the number of transactions. It should be noted, however, that the

Chinese state had very strict restrictive measures to prevent the spread of the virus, so the shock, especially in terms of volumes, was very harsh for this reason alone.

Ionașcu (2020) examines the effects of the corona pandemic on the Romanian housing market, which has undergone uncontrolled price and construction volume growth since the financial crisis. The mortgage growth has been very strong in the country, suggesting that there is a risk of a housing boom in the country caused by credit financing. The initial shock of the pandemic significantly reduced people's desire to buy a home and the demand for housing fell by as much as 70 % and the number of apartments for sale by about 60 % in the first few weeks. This is affected by both strict restrictive measures and people's uncertain future economic prospects. Prices remained relatively stable during the pandemic, but gradually listing prices for both new and old apartments in Romania's largest cities began to fall slightly from month to month, averaging 1-2 %. Similar observations have been made in the Turkish housing market. There was a significant decline in real estate sales in March-May 2020 when real estate sales were up 42 % lower than at the same time last year, but in June 2020 the market began to recover, so the correction took place fairly quickly (Tanrıvermiş, 2020).

Del Giudice, De Paola & Paolo Del Giudice (2020) study the effects of the corona pandemic on housing prices in Italy, Campania region. There has been an upward trend in house prices in the area before the COVID-19 since 2014. The model that estimates changes in house prices due to the COVID-19 pandemic is obtained from a shock to the regional economic and real estates factors, like employment rates and housing sales index, using the economic model Lotka-Volterra.

Del Giudice et al. (2020) represent two different schemes, short- and medium-term scenarios for the effects of the pandemic. The first, short-term period, has been calculated from the beginning of the lockdown (early March 2020) to the first half of May 2020 (the beginning of the slow restart of the economic recovery). During this period, housing prices in Campania are estimated to have fallen by −4.16 %. According to the medium-term scenario (end of 2020 – the beginning of 2021), the fall in house prices in the Campania region is defined as −6.49 %, so the effects of the pandemic on house prices appear deferred.

In their study, Allen-Coghlan and McQuinn (2020) perform scenario analysis such as Del Giudice et al. (2020) from the Irish housing market. According to the paper, house prices in Ireland are expected to fall over the next 18 months as a result of the COVID-19 downturn due to a sharp decline in the mortgage market and a decline in household disposable income.

There is also some research available on the effects of the COVID-19 in the U.S. housing market. Liu and Su (2020) study the effects of a pandemic on housing location demand. The main finding in the paper is that the pandemic has led to a sudden shift in housing demand away from densely populated areas and neighborhoods close to city centers. The reduced demand for housing in densely populated areas is partly due to the increase in teleworking and the declining attractiveness of consumption opportunities (e.g. restaurants) due to the need for social distance. Furthermore, the demand fell more sharply in the more expensive area the apartment is located. An important observation in the paper also shows that the findings are not due to a sudden lockdown at the beginning of a pandemic outbreak. As the pandemic progressed as the national U.S. housing market recovered, declining demand for density intensified.

In the United States, as in many other countries, housing sales volume fell sharply at the start of the pandemic. Yörük (2020) shows in his paper that by mid-April, certain U.S. housing markets were down more than 60 % from the decline in new homes and expected home sales compared to the same period last year and this observation is also supported by D'Lima, Lopez & Pradhan (2020).

Zhao (2020) is studying the effects of the coronavirus on U.S. housing market prices in various zip code areas. In March 2020, the Fed lowered the Federal funds rate by as much as one percentage point to 0 - 0.25 percent. Such a large drop in the interest rate at one time is very exceptional. Most recently, the Federal funds rate was zero during the 2008 financial crisis. This triggered a 30-year fixed mortgage rate to record lows of 2.97 percent. In mid-July 2020, the rate fell again and was the seventh record low that year. At the same time, housing prices have risen.

The study highlights a few key points that have occurred in the U.S. housing market during the corona pandemic. After the initial shock of March 2020, house prices started to rise faster with the Fed's actions than before the pandemic. Growth in the average price per square meter is faster than in any four-month period after the 2007-2008 financial crisis. The supply of housing, on the other hand, has also fallen sharply since spring 2020, but demand has increased, which is reflected in increased browsing activity on Internet housing sites. Besides, house prices have risen more in lower-wage postcode areas, but demand has been strong in both low- and high-wage areas. For low-wage levels, this is explained by low interest rates and readily available loans, while in high-wage areas, demand may be due to the so-called FOMO (fear of missing out) phenomenon. Also, the paper indicates that housing prices have risen very evenly in both rural and urban areas so the research result of Liu et al. (2020) might be not directly reflected negatively in housing prices in urban areas.

2.4.1 Conclusions from the global pandemic studies

Previous research shows that the COVID-19 pandemic, like global pandemics in general, has clear implications for the housing markets, although there is still very limited academic research on the subject. The development of the housing market is affected by both the size of the population and people's incomes, and with unemployment and deaths, the corona pandemic harms both. At the global level, the shock to the housing market in the spring of 2020 was fierce everywhere, but the recovery from this has been very different between countries. Strict restrictive measures and lockdowns caused the volume of home sales to a non-existent level around the world compared to the normal situation. At this point, the Finnish and Helsinki housing markets are no exception. Francke et al. (2021) show that such a shock caused by an infectious disease was not only caused by the corona pandemic, but was also in the 16th and 17th centuries.

In the United States, for example, the Fed's record-breaking economic stimulus measures prompted the housing market to recover rapidly, as Zhao (2020) shows, although the initial shock reduced transactions by as much as 60 % (Yörük, 2020). The situation can be compared to Finland, but on a larger scale. In contrast, countries where the corona pandemic is believed to have more far-reaching negative effects on the housing market are characterized by certain factors. In Italy, for example, the impact of a pandemic has been severe, as in Del Giudice et al. (2020) show, but the country's economic situation has long been frail. The corona pandemic has further weakened the situation and, besides, the housing market has been in a downturn for years before the pandemic (European Commission, 2017). Instead, the Romanian and Irish housing markets, for example, are characterized by cyclicality. In Romania, a record number of mortgages have been granted before the COVID-19 pandemic, but the country's weak economic situation, corruption and people's insecurity are also weakening the outlook for the housing market (Ionașcu, 2020).

During the pandemic, there has been a lot of speculation in Finland about the phenomenon where people are moving out of growth centers, and this has also been reflected, for example, in the increased demand for summer cottages. The phenomenon is also familiar at the global level, as Liu et al. (2020) study from the United States shows. However, Zhao (2020) states that the phenomenon has not affected housing prices in cities in the US. It is interesting to study what the situation is like in Helsinki and whether, for example, the increased demand in rural areas during the pandemic has provided good opportunities for buyers in Helsinki. Besides, Qian et al. (2020) state in their study that the COVID-19 pandemic has affected housing prices in China, especially in high-infection areas. In the case of Finland, the situation is opposite, as Helsinki has had the highest number of infections cumulatively, but the rise in house prices has been the most stable.

3 Theory and methodology

This chapter focuses on introducing the key theory behind the methods used in the study. The study estimates the price equations for dwellings using a model based on hedonic price functions theory, in which the purchase prices of dwellings are explained both by the physical characteristics of the dwellings and by the regional and locational variables associated with the dwellings. The purpose is to analyze the relationship between housing prices and characteristics in the Helsinki housing market before and after the coronavirus pandemic and to examine whether, during or before the pandemic, there are significant differences in the attributes that are valued when buying a dwelling. The same model will be utilized later in this study when examining whether there has been a clear buyer or seller favoring market for transactions in the Helsinki area.

This study will focus more deeply on the empirical analysis itself, so the paper seeks to present the hedonic price functions theory quite briefly but so that the reader gets as comprehensive an understanding of it as possible. We also briefly discuss problems related to the utilization of the hedonic price function as well as issues related to the choice of the optimal function form. Furthermore, this paper focuses on exploiting OLS regression on the one hand because of its simplicity, but also because it is a natural starting point for econometric modeling.

3.1 Hedonic price functions theory

One of the pioneers of the hedonic pricing method is considered to be Andrew Court, who in 1939 studied the automotive industry and the impact of various features on car prices (Goodman, 1998). However, the method itself did not originate until 1966 from the theory presented by Kelvin Lancaster, in which consumers are interested in the characteristics of commodities, whereas previously it was thought that the commodity itself would produce a utility for the consumer. In the Lancaster model, consumers are looking for feature combinations that maximize utilities and therefore different product combinations are possible. Thus, the model is well suited to the examination of consumer goods markets (Lancaster, 1966).

The theory of total utility formation was continued by Sherwin Rosen in 1974 by presenting a theoretical model for differentiated commodities such as dwellings. In this model, the consumer seeks a utility-maximizing feature, or a combination thereof, by purchasing a single product, contrary to what Lancaster (1966) proposed, thus applying to the consumer durables market. The apartment can be thought of as a set of its various features, for which, according to Rosen (1974), values measured in money can be derived. The theory has been applied extensively in housing market research and Rosen's hedonic pricing theory is also applied in this paper, which is presented in more detail in this section.

At the core of hedonic price theory is the hedonic price function. Suppose that product n has characteristics $z = (z_1, z_2 \dots, z_n)$, where the components of z $(z_1, z_2 \dots, z_n)$ describe the different features of the product. Each consumer can consume a commodity containing different amounts of vector z and different prices are paid for the commodities, with a number of marginal prices depending on the amount of vector z. In theory, the characteristics are assumed to be objectively measurable so that all consumers observe characteristics z as equivalent, but their valuation may vary. Furthermore, there is a myriad of commodities with different characteristics on offer, giving consumers a lot of choice. Products have an individual market price that is always associated with a certain value of vector z, and thus the market implicitly reveals a hedonic price function $p(\boldsymbol{z}) = (z_1, z_2 \dots, z_n)$, that combines prices and characteristics. The price function indicates the minimum price for each feature combination (Rosen, 1974).

3.1.1 Consumer's decision problem

Suppose a consumer buys only one unit of a heterogeneous product with all the characteristics z are considered to be adequate. In this case, consumers want to buy more these features, making the function $p(\boldsymbol{z}) = (z_1, z_2 \dots, z_n)$ increasing in terms of all its characteristics. The function can be nonlinear and the assumption of linearity is valid, according to Rosen (1974), only in a market where the consumer has no possibility of arbitrage. However, the nonlinearity assumption applies especially in the housing market, where commodities are indivisible (Rosen, 1974). Every consumer has a utility function $U(x, z_1 \dots, z_n)$, where x is the consumption of a commodity other than housing and the price of x is set to 1. The function U is assumed to be concave and increasing with respect to its factors. By setting the price of the consumer utility function constant, the relative income y of the consumer can be measured. The value of consumer income y is obtained as a function $y = x + p(z)$, and by maximizing this function we get the maximum utility to the consumer (Rosen, 1974):

$$\max U\ (x, z_1 \dots, z_n) \tag{1}$$
$$so\ that: y = x + p(z)$$

The solution is x and $(z_1, z_2 \dots, z_n)$, which satisfy the first-order conditions as well as the budget constraint. In this case, the consumer has the desired amount of each feature in the optimum (Rosen, 1974; Laakso, 1997).

$$\frac{\partial p}{\partial z_i} = p_i = \frac{Uz_i}{U_x}, \qquad i = 1, \dots, n. \tag{2}$$

The valuation of the various characteristics is presented as a bid function of the buyer $\theta(z_1, z_2 \dots, z_n; u, y)$, which is included in the utility function according to Rosen (1974) as follows:

$$U(y - \theta, z_1, \dots, z_n) = u \tag{3}$$

In fact, the bid function $\theta(z_1, z_2 \dots, z_n)$ describes the consumer's appreciation for a particular characteristics. This means the willingness to consume alternative properties of the commodity (from alternative configurations) at a given level of utility and income (Rosen, 1974). Besides, the following properties can be differentiated for the bid function:

$$\theta_{z_i} = \frac{Uz_i}{U_x} > 0,$$
$$\theta_u = \frac{-1}{U_x} < 0, \tag{4}$$
$$\theta_y = 1,$$
$$\theta z_i z_i = \frac{U_x^2 U_{ZiZi} - 2U_x U_{z_i} U_{xz_i} + U_{z_i}^2 U_{xx}}{U_x^3} < 0$$

We can see that the bid function is slowly increasing with respect to *z*. At the same time, the marginal utility of *z* is declining. In this case, the bid function θ describes the amount of money that the consumer is willing to pay for characteristics *z*, while $p(\boldsymbol{z})$ reflects the minimum price that the consumer has to pay for characteristics *z* on the market. Rosen (1974) shows that the maximization of the utility is then:

$$\theta(z^*; u^*, y) = p(z) \ and, \tag{5}$$
$$\theta z_i(z^*; u^*, y) = p_i(z^*)$$

In the above formulas, $z^*$and u^* are the optimal values of z and u. Then the optimum is reached at the point where $p(z)$ (hedonic price function) and the optimal bid function are tangent to each other. At the same point, the marginal price and the marginal value intersect. The following Figure 7 illustrates the choice situation of two consumers with respect to the characteristic z_1. Their utility functions are the same, which is not actually a realistic assumption. However, the bid functions are different, due to income differences, for example. In the optimum, consumer 1 selects a product with a smaller number of attribute z_1 than consumer 2 (Rosen, 1974; Pakarinen, 2018: 11-12).

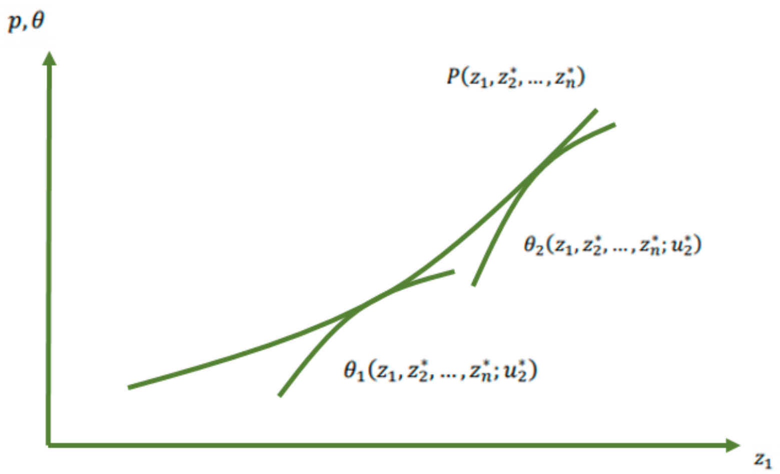


Figure 5. The bid functions of two different consumers to characteristics z_1.
Source: Pakarinen, 2018: 12

3.1.2 Producer's decision problem

Rosen (1974) treats supply decisions of heterogeneous commodities with different characteristics of a producer in the same way that consumer behavior has been examined above. In this case, it is considered what kind of multidimensional product or assembly is useful to produce. The number of z-assembled products manufactured by the company is denoted by $M(\boldsymbol{z})$. Also, we assume that cogeneration is not possible, videlicet each production plant of the company operates independently of the others. Nor does any production plant dominate the market. The producer's cost function is denoted $C(M, z; \beta)$, where the parameter β reflects the differences between the plants in terms of, for example, technology, input costs or other factors. Besides, we assume that *C* is convex and $C_m > 0$ and $C_{zi} > 0$. Profit maximization occurs when both *M* and *z* are both optimal.

$$\pi = Mp(z) - C(M, z;\ \beta) \tag{6}$$

It should be noted that for each commodity composition, *z* is determined by the hedonic price function $p(\boldsymbol{z})$. The market is competitive, so the function is independent of quantity *M*. The optimal choice according to unit price *z* and production volume can be defined according to Rosen (1974) as follows:

$$p_i(z) = \frac{Cz_i(M, z_1, \dots, z_n)}{M},\ i = 1 \dots n \tag{7}$$

and

$$p(z) = C_m(M, z_1, \dots, z_n) \tag{8}$$

At the optimum point, the marginal return of a characteristic added corresponds to the marginal cost. Thus, products are manufactured until its unit price $p(\boldsymbol{z})$ meets the marginal cost. Furthermore, as for consumers, the offer function $\phi(z_1, \dots, z_n; \pi;\ \beta)$ can be defined for enterprises as well. This function reflects the unit price at which a company gains a standard profit when accepting models with different characteristics when the production volume is optimally selected. The offer function is obtained by solving the following equations (Rosen, 1974; Pakarinen, 2018: 13):

$$\begin{gathered} \pi = M\phi - C(M, z_1, \dots, z_n) \\ C_m(M, z_1, \dots, z_n) = \phi \end{gathered} \tag{9}$$

The offer function is obtained by removing the quantity parameter *M* from the first equation, after which $\phi()$ is solved with respect to the parameters z, π and β. Besides, $\phi_{z_i} = \frac{Cz_i}{M} > 0$ and $\phi_n = \frac{1}{M} > 0$. In this case, the optimum is (Rosen, 1974; Pakarinen, 2018: 13-14):

$$p(z^*) = \phi(z_1^*, \dots, z_n^*;\ \pi^*, \beta) \tag{10}$$

and

$$p_i(z^*) = \phi_{z_i}(z_1^*, \dots, z_n^*;\ \pi^*, \beta),\quad i = 1, \dots, n \tag{11}$$

Figure 8 shows the offer functions of two different producers in terms of characteristics. The characteristics configurations of the end products are different because the companies' production processes and cost functions are different (Rosen, 1974; Pakarinen, 2018: 14).

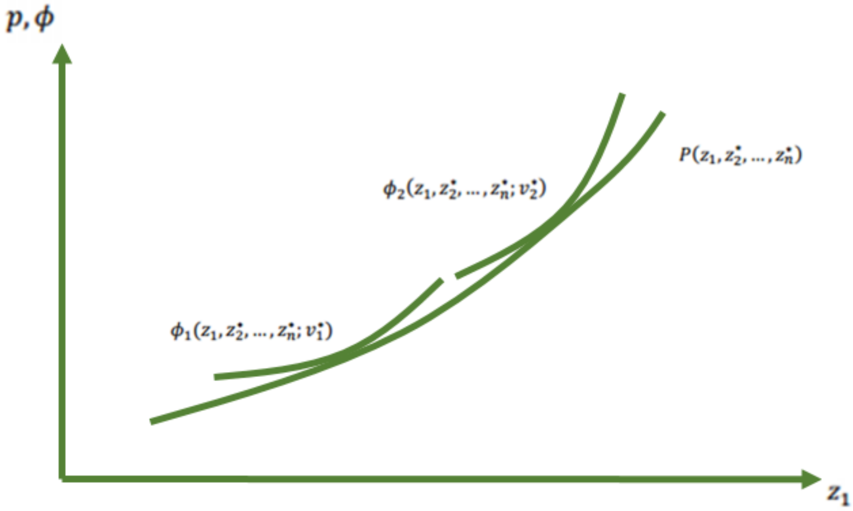


Figure 6. The offer functions of two different producers to characteristics z_1.

Source: Pakarinen, 2018: 14

3.1.3 Equilibrium

In equilibrium, the producer offer function and the consumer bid function are side by side, so that their gradient at each point is the same as the gradient of the hedonic price function $p(\boldsymbol{z})$. Furthermore, this results in the hedonic price function being a common curve of the producer offer function and the consumer bid function. This situation is illustrated in figure 9. The balance is determined by the decisions of all producers and consumers, and the assumption is that the market is perfect. The basic problem of the theory is that supply and demand depend on the whole hedonic price function $p(\boldsymbol{z})$. In the model, market equilibrium presupposes the existence of a price function $p(\boldsymbol{z})$ in which the supply of products with z characteristics corresponds to demand at all values of z. If supply and demand do not match at current prices for a given product model, the change will cause substitution effects as well as shifts in all commodity characteristics (Rosen, 1974; Brotherus, 2011; Pakarinen, 2018: 14-15).

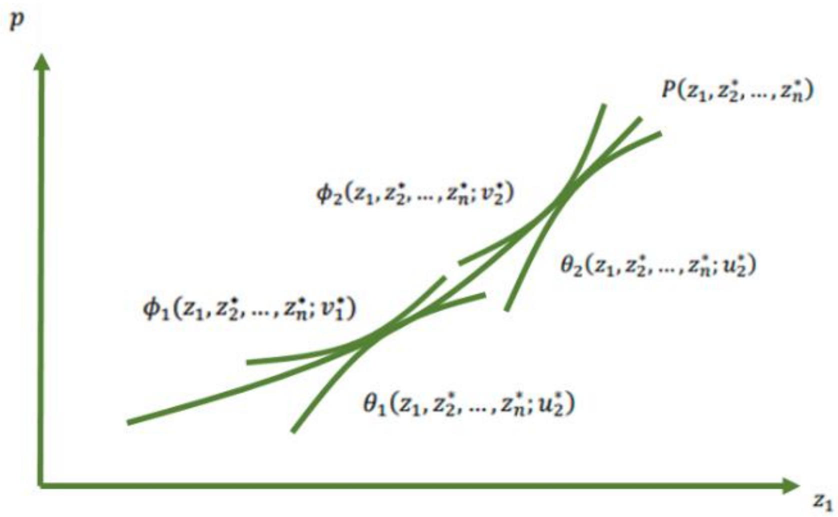


Figure 7. Equilibrium with two producers and consumers.

Source: Pakarinen, 2018: 15

3.1.4 Challenges in utilizing the hedonic price function

Although Rosen's theory has been widely utilized in housing market research, the equilibrium assumption presented in the last section has also been much criticized in the academic literature, such as Chin & Chau (2003) and Bartik & Smith (1987). The main assumption of the model that consumers are always aware of all available dwellings on sale and thus adapt their consumption to the new equilibrium state according to income, prices, or preferences is not a typical situation in the housing market. First, the information in the housing market is very incomplete because, as previously presented, sellers have different information about dwellings than buyers, and the buyers themselves are in an unequal position with each other. The housing market has high transaction and search costs and the consumer needs to receive significant additional benefits from exchanging an apartment to exceed these trading costs.

Furthermore, the choice of explanatory variables serves as an essential factor in creating hedonic regressions. It is possible to utilize an infinite variety of variables in the model. In the case of ignoring relevant variables, the estimated parameters of the model properties may suffer from the omitted variable bias, which distorts the results of the entire hedonic model. In housing, this bias always exists, because not all characteristics affecting dwellings can be measured directly, such as factors related to the neighborhood of the dwelling. Furthermore, the significance of this bias in prices in the model is also not easy to predict, as it depends, among other things, on the correlation between the variables selected for the model and the variables omitted (Abbott & Klaiber, 2011; OECD et al., 2013).

Malpezzi (2003) and Sopranzetti (2015) list the most typical variables relevant for inclusion in hedonic models of housing. Based on this framework, the choice of variables will be made for this study as well.

Table 5: The most used variables in hedonic regressions

Structural characteristics	Age of the dwelling, square footage of the dwelling, total number of rooms, known defects, existence of a sauna or balcony, floor of the dwelling, fireplaces, garages etc.
Characteristics of neighborhood	Median salary of neighborhood, neighborhood quality, quality of schools in the neighborhood.
Characteristics of location	Distance to schools or shops, accessibility to public transport, proximity to downtown.
Data collection date	Relevant if the data have been collected over a period of several months or years.

The more variables used, the better the degree of explanation of the model. The problem, however, is that then the variables in the model are more strongly correlated with each other, i.e., multicollinearity increases and parameter estimation becomes biased. This is typical especially in hedonic price models modeling dwellings, for example, as the number of rooms increases, the surface area of the dwelling increases (Laakso, 1997; Pakarinen, 2018: 22). In order to test multicollinearity, this research utilizes, for example, VIF values, the equation of which can be found below (R_i describes the coefficient of determination). If all variables are independent of each other, the VIF value becomes 1. In general, it can be said that multicollinearity is a problem if the VIF value becomes more than 10 (Hair, Black, Babin & Anderson, 2009).

$$VIF_i = \frac{1}{1 - R_i^2} \quad i = 1,2, \dots, n \tag{12}$$

Besides, in assessing the suitability of the model, the variances of the error terms are considered, which should remain constant, in other words, homoscedastic as the X variables change. If the variance of the random variable is not constant, there is heteroscedasticity in the model and this may affect the statistical significance of the regression coefficients (Hair et al. 2009). In this study, the aim is to observe possible heteroscedasticity employing different scatter plots and conducting Breusch-Pagan tests (Breusch & Pagan, 1979). It is also noteworthy that the monotonicity of variables in the housing market is difficult to assess. As an example, Pakarinen (2018: 23) raises the effect of the age of an apartment on its price: new apartments are automatically more expensive, especially because they represent the latest technology. Furthermore, the old apartments are also expensive, because they are often located in the city center. On the other hand, people also appreciate the old building stock, if the apartment has been well taken care of, which is positively reflected in the prices.

To increase the reliability of the model, data for this study are mainly collected from single source. If several data sources are used together, problems can arise, for example, because the variables may not have been measured consistently, even if the data itself is valid. According to Pakarinen (2018: 22), this is especially typical when analyzing housing characteristics, as these features can be stored in very different ways.

3.1.5 Parametric hedonic pricing models and function form selection

This study utilizes OLS regression in the estimations and the empirical part of the paper is based on a model built on hedonic price theory. In academic research of the housing markets, the use of linear models has been common and this study focuses on OLS regression because, firstly, it is an easy and natural starting point for econometric modeling and, secondly, it is not the worst alternative, which is also evidenced by its popularity in previous research (Pakarinen, 2018: 24).

There has been a lot of controversy regarding the choice of function form when estimating the HPF (hedonic price function), and researchers have not agreed on the optimal function form. Even Rosen (1974) does not consider the choice of the optimal form of function in his article, while some studies go very comprehensively through different alternatives to modeling (Laakso, 1997).

Pakarinen (2018: 24-25) states that in recent decades it has been common to utilize more flexible forms of function. However, the most commonly used function in the academic literature is the linear function due in particular to its ease of use. Its results serve as an easy point of comparison if more complex models and analyzes are also applied in the study, as Pakarinen (2018) does in his dissertation. Ohsfeldt (1988) shows that the simplest form of function, the linear model, gives sufficiently good results for the individual coefficients of the variables and the results are based on monetary values. Furthermore, Laakso (1997) indicates that most studies focus on utilizing a linear function, a log-linear function, or a semilog function when estimating HPF. The log-log function is also utilized in this study.

In the linear model, the function takes a very simple form:

$$P = \beta_0 + \beta_1 z_1 + \cdots + \beta_n z_n + \varepsilon \tag{13}$$

In the model β_i $(i = 0,1, \ldots, n)$ are the coefficients obtained from the regression and z_i describes the characteristics of the dwelling. Besides, ε is the disturbance or the error term. In the semilog function, instead, the price of the dwelling, the dependent variable, is presented on a logarithmic scale. According to Laakso (1997), this makes it possible to estimate non-monotonic relationships between price and an independent variable. The weakness of the function can be considered to be that it assumes that the marginal price of the price function increases monotonically, which cannot be considered a plausible assumption. The coefficient of the explanatory variables indicates the percentage change in price as the variable increases by one unit.

$$log(P) = \beta_0 + \beta_1 z_1 + \cdots + \beta_n z_n + \varepsilon \tag{14}$$

In the log-log model, in addition to the dependent variable, the logarithm is also taken from the explanatory variables. The logarithm can be taken from continuous variables, such as the size of the dwelling.

$$log(P) = \beta_0 + \beta_1 \log(z_1) + \cdots + \beta_n \log(z_n) + \varepsilon \tag{15}$$

The function allows marginal prices to be decreasing, increasing, or constant depending on the relationship between price P and characteristics z_i $(i = 1, \ldots, n)$. The estimated parameter values show how much the percentage change in the price of the dwelling is when a percentage change is made to the characteristics z_i (Laakso, 1997).

This study will take advantage of the log-log function. The use of relative terms alleviates the comparison of the results of the estimations, and in addition, log-log modeling allows us to reduce the heteroscedasticity of the models as well as multicollinearity problems.

4 Data and descriptive analysis

This chapter focuses on presenting the data used in the study as well as the choice of variables. First, however, we present a descriptive analysis of the effects of the COVID-19 pandemic on the Finnish and Helsinki housing markets. Based on this analysis, it becomes more reasonable to make comparison of this paper's results, especially when assessing the impact of a pandemic on living conditions and preferences.

The paper utilizes two different datasets that describe the situation before and during the outbreak of the COVID-19 pandemic. Only dwellings classified as owner-occupied are included in this model and the various occupancy and co-ownership properties are eliminated due to very different prices and ownership restrictions. Of the housing types, only dwellings classified as a block of flats that were built in 2018 or before are included. Besides, we justify why it makes sense to subdivide the data both according to apartment types and regionally.

4.1 Descriptive analysis of the effects of the COVID-19 pandemic on the Helsinki and Finnish housing markets

The impact of the COVID-19 pandemic on the Finnish housing market was very sudden, however, following very similar principles as previous crises, which were presented in Section 2.3.2. Housing sales in Finland were at a good pace until March, but in April sales volumes fell by about 30 %, which is a collapse comparable to the beginning of the recession of the 1990s. The effect on prices was less significant and the decrease was around 5 percent. However, markets recovered rapidly and urbanization continued, with the population of growth centers growing even in the early stages of a pandemic (Brotherus, 2020b; 2020c; KVKL, 2021). Housing prices returned to normal as early as the third quarter of 2020. In the last quarter of the year, prices started to rise rapidly, with a growth of about 1.5 percent for the whole year and even more than 4 percent in Helsinki (Keskinen et al. 2021; PTT, 2021).

This shows that demand in the housing market was very strong in the latter part of 2020, and the following graphs (Statistics Finland, 2021) illustrate the volume of transactions at the level of Finland and Helsinki as a whole. The graph shows that transaction volumes in Helsinki dropped by as much as 31 percent in April 2020, while the decline for the whole country was 28 percent. Both in Helsinki and for the country as a whole, the correction took place upwards already in June, but especially in September, the Helsinki housing market became more active, rising by more than 24 percent (the whole country by 11 percent).

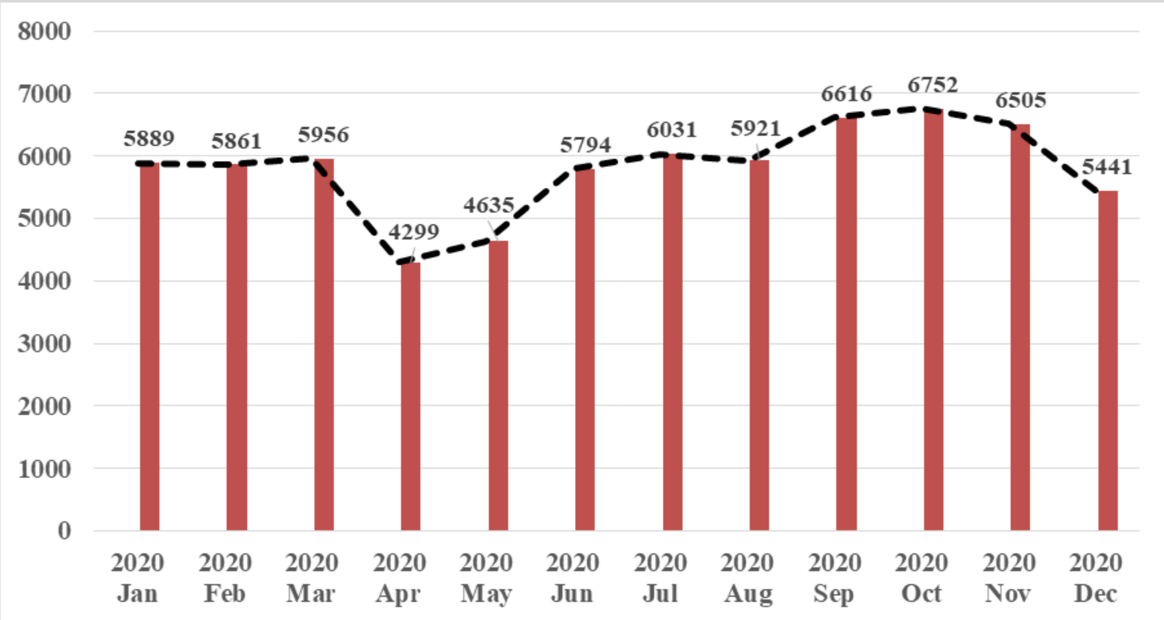


Figure 8. Housing transaction volume in Finland in 2020 monthly.

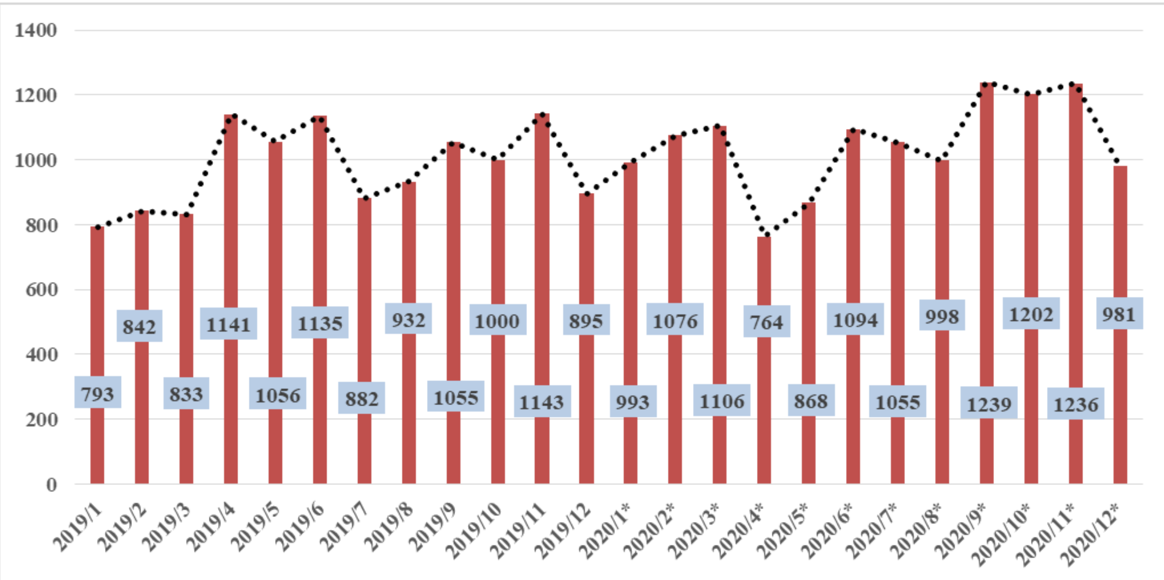


Figure 9. Housing transaction volume in Helsinki in 2020 monthly.

*Data for 2020 is preliminary

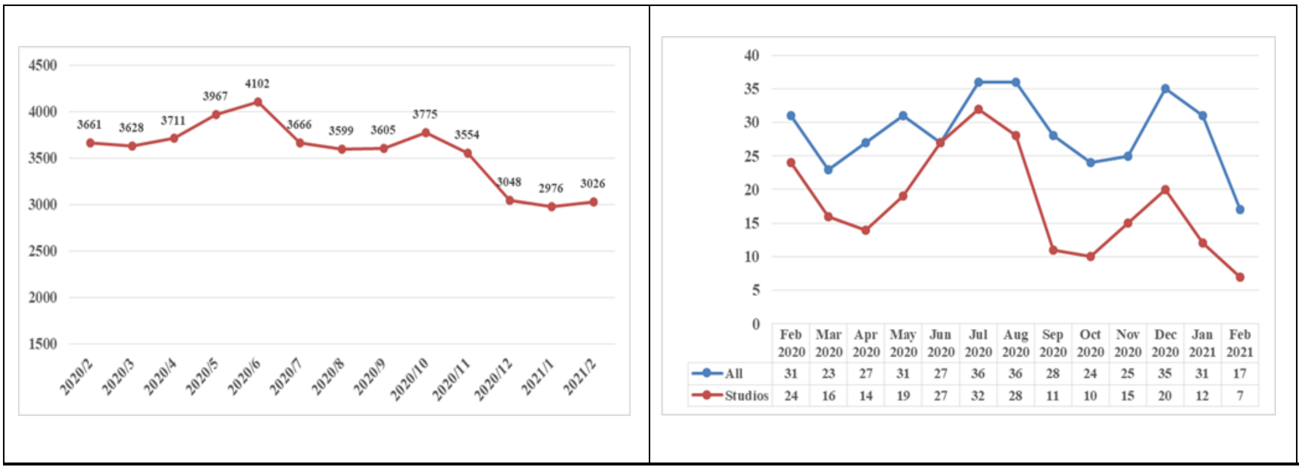
Statistics show that the demand for housing in Finland, and especially in growth centers, has been exceptionally strong in 2020. The euro area has been in difficulty repeatedly since 2008, which has made it more difficult to raise living standards and, as a result, household wealth has shrunk. As a positive side effect for homeowners, loan interest rates remain low for perhaps even decades. Finland's standard of living has developed slowly, creating an imbalance between public expenditure and revenue. The corona pandemic has further accelerated indebtedness. Furthermore, population aging and low birth rates are undermining economic growth and reducing investments, which is reflected in central banks' monetary policy and interest rates (Keskinen & Brotherus, 2021b). In 2020, mortgage loans were acquired in Finland up to 4.5 percent more than in 2019 (PTT, 2021). This describes the strong situation in the housing market, which is also supported by OSF's (2021b) table, according to which people's desire to buy an apartment in the next 12 months is now the largest in the entire measurement history (25 years).

Table 6: Intention to buy a dwelling in the next 12 months (% of consumers)

Average 10/1995-	Max. 10/1995-	Min. 10/1995-	02/2020	01/2021	02/2021	Outlook
12.7	18.1	9.1	14.4	16.6	18.1	++ very good

Source: OSF, 2021b

The attached Figure 10, built from the database of Finland's best-known housing service, Etuovi.com (2021), shows that the number of dwellings for sale in Helsinki has decreased considerably over the past year (more than 17%). At the same time, the marketing time of dwellings has decreased significantly, especially for studios, which contributes to the strong demand for small apartments.



a) Number of apartments for sale in Helsinki b) Average marketing time (d) in Helsinki

Figure 10. Number of apartments for sale in Helsinki and average marketing times.

The COVID-19 pandemic has affected housing choices and changed people's living conditions in Finland as well. During the pandemic, people may have emphasized, for example, their peace, teleworking opportunities, and good transport connections when choosing an apartment. In cities close to the Helsinki metropolitan area, such as Porvoo and Kotka, house prices have increased significantly in 2020 (PTT, 2021). People's interest in holiday homes increased in 2020 and sales volumes increased by as much as 35 % compared to the previous year (KVKL, 2021). Furthermore, demand for detached houses has also increased significantly, and in cities with more than 100 000 inhabitants, detached house prices rose by 5.4 percent (PTT, 2021). The pandemic also made the business of short-term apartment rental unprofitable, and in Helsinki, many Airbnb apartments switched to long-term rental. In Lapland, for instance, the impact is much greater when foreign tourists using apartments have disappeared (Brotherus, 2020b).

The significant increase in the sales volume of detached houses is shown in Table 6 (Statistics Finland, 2021). It should be noted that the data in the table are only preliminary and will not be fully updated until May 2021.

Table 7: Sales volume of apartments in Finland

	Condominiums sold	Detached houses sold	Sum	Annual change
2015	63 214	13 993	77 207	8,17 %
2016	62 935	14 429	77 364	0,20 %
2017	63 358	14 920	78 278	1,18 %
2018	62 400	14 683	77 083	-1,53 %
2019	63 298	15 317	78 615	1,99 %
2020*	69 700	16 150	85 850	9,20 %

* Data for 2020 is preliminary

4.2 Data

The research data were collected using the Asuntojen.hintatiedot.fi database, which is an open service developed by the Housing Finance and Development Centre of Finland and the Ministry of the Environment. In addition, the website has been developed in co-operation with the Central Federation of Finnish Real Estate Agencies, Kiinteistömaailma Oy, Huoneistokeskus Oy, Aktia Kiinteistönvälitys Oy and RE/MAX Finland. The service can be used to retrieve Finnish housing transaction data for the last 12 months. The data is divided into two parts, and they only include transactions for old dwellings in Helsinki (built in 2018 and older). The first data is from the period 5/2019 to 12/2019, which reflects the time before the corona pandemic, and the second is from the same period one year later, 5/2020 to 12/2020, when the pandemic had already hit Finland. Transaction prices are based on their actual selling price, not the asking price. This is important in determining the hedonic price function, as the correct selling price can often deviate much from its asking price, in which case the correct hedonic price cannot be determined because home buyers may bargain on the selling price. The same is also stated by Pakarinen (2018: 31).

The total data collected initially had 4220 data points, but after processing we end up with 4015 observations. For these reasons, inter alia, data points were eliminated:

1. The observation is clearly not an apartment, but a garage, for example.
2. The information entered has clear typographical errors or is incomplete.
3. The observation does not specify the number of rooms (such as 1-2 rooms instead of clearly 1 or 2).
4. The construction year of the apartment has been reported as 2019, 2020 or 2021, so it can be interpreted as a new dwelling, depending on the dataset. To harmonize, this study will utilize apartments built in 2018 and older.

Even after processing, the data set of the thesis may contain factors that distort the results of the research. For example, a sold apartment may be covered by the HITAS system, in which case it is on the City of Helsinki's rental plot and a price cap has been set for the apartment, with which it can be sold. Therefore, these apartments are slightly cheaper than the market price of similar apartments. For example, Vainio (1995) and Huttunen (2009) do not care about the existence of possible HITAS dwellings in the data, but Laakso (1997) eliminates these. This study assumes that the number of HITAS dwellings is very small and does not affect modeling. Also, dwellings may be sold, for example, among relatives or acquaintances at significantly lower prices than the market price, but in this case, real estate agents are not usually used due to the commissions paid to them so therefore it is assumed that the data of this study do not include such transactions and the same assumption is made by Vainio (1995) and Huttunen (2009).

4.2.1 Variables

In Section 3.1.4, this study presents a typical breakdown of hedonic price model variables in the housing context according to Malpezzi (2003) and Sopranzetti (2015). The variables utilized in this study are presented in Table 8. Structural variables include the age of the dwelling, an area in square meters, number of rooms, floor level and several dummy variables that describe the existence of a sauna and balcony, plot ownership, elevator, condition of the apartment, and whether the apartment is on the top or ground floor. Besides, the importance of the elevator in the price of the dwelling is tried to explain better by a variable that describes the location of the dwelling on the top floor in addition to the fact that the building has an elevator. The neighborhood variables are the average annual income level in the district and the average price per square meter in the area. In addition, the data is divided locally according to the zip codes into two separate groups, which form the locational variables. They are discussed in more detail in the next section. The annual income level and the average price per square meter in the region are extracted from Statistics Finland's database and the estimation is done at the zip code level.

Table 8: Descriptive statistics of the whole data

Variable	Minimum	Maximum	Mean	Std. Deviation	Skewness
Price	82 000	2 350 000	313 833,55	208 528,014	3,156
District price (€/m2)	2037	8327	5127,34	1657,773	-,051
Area (m2)	14,000	271,000	59,29741	26,249095	1,702
Floor level	1	13	2,95	1,641	,910
Average income on area	20 689	81 403	29 495,37	8015,845	1,903
Apartment age (years)	2	170	57,03	27,738	,072
Number of rooms	1	8	2,32	,999	,783
Bottom floor	0	1	,20	,400	1,506
Top floor	0	1	,23	,420	1,295
Elevator	0	1	,59	,492	-,359
Top floor and elevator	0	1	,09	,290	2,811
Good condition	0	1	,59	,492	-,352
Average condition	0	1	,37	,482	,558
Bad condition	0	1	,04	,189	4,903
Own plot	0	1	,69	,463	-,822
Sauna	0	1	,15	,358	1,951
Balcony	0	1	,32	,465	,788

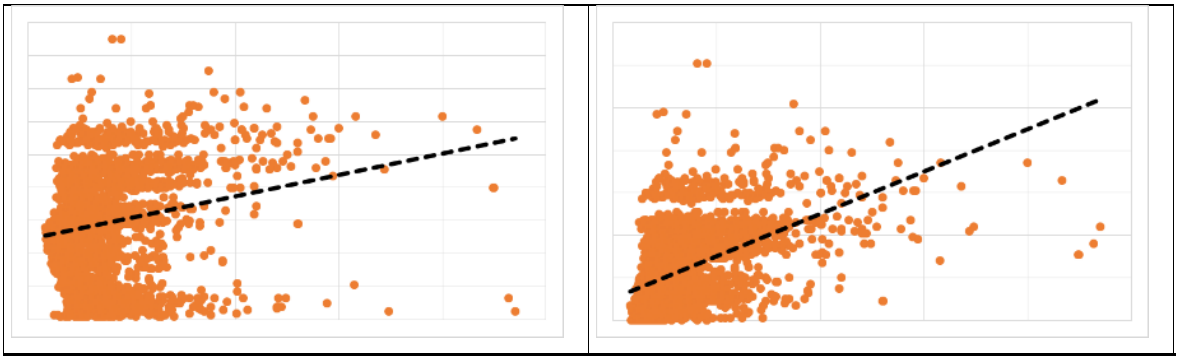
From the table, we can see that the average apartment in the data is about 57 years old, a one-bedroom apartment with a price slightly over 310 000 euros and size about 59 square meters. The price of housing is strongly positively skewed, which shows that there are also a lot of remarkably expensive apartments in the data, and the most expensive apartments sold are worth more than 2 million euros. The measurement of skewness is explained in more detail in Chapter 4.

About 69 percent of the apartments in the data are located on an own plot. The plot is of great importance for the price of the apartment because when the building is on a rented plot, it can be bought with much less capital. In this case, however, the cost of housing is considerably higher, as the rent is paid as part of the monthly maintenance charge. Also, the buyer of the dwelling may have the right to redeem ownership of the plot by paying a specified fixed price. The material does not include housing-specific maintenance fees, so plot ownership can assume to have a significant impact on the modeling of the study. In other studies, for example, Vainio (1995) and Brotherus (2011) find that own plot raises the price of the dwelling by about six percent.

More than 30 percent of the dwellings in the data have a balcony and about 15 percent of the observations include a sauna, which is typical for Finnish apartments. These are common features, especially for slightly newer and larger apartments. The distribution between the top and bottom floors is fairly even, with 23 percent of dwellings located on the top floor and about 20 percent on the ground floor. The average floor level is about 3 and the maximum floor level in this data set is 13. About 59 percent of condominiums have an elevator, but somewhat surprisingly, only about 9 percent of the apartments in the dataset are located on the top floor and in a condominium with an elevator. Thus, it could be assumed that there are quite a few small apartment buildings in the data, in addition to very old dwellings, which rarely have an elevator.

The data show that the majority (59 percent) of dwellings are classified as in good condition and about 37 percent as in average condition. Only four percent of apartments are in bad condition. It is worth remarking, that the classification is a subjective view of the real estate agent that may differ from the actual condition. Pakarinen (2018: 34) mentions that the small number of apartments in bad condition can be explained by the fact that brokers easily see the condition of the apartments in too positive a light. Furthermore, sellers may be reluctant to sell dwellings in very poor conditions.

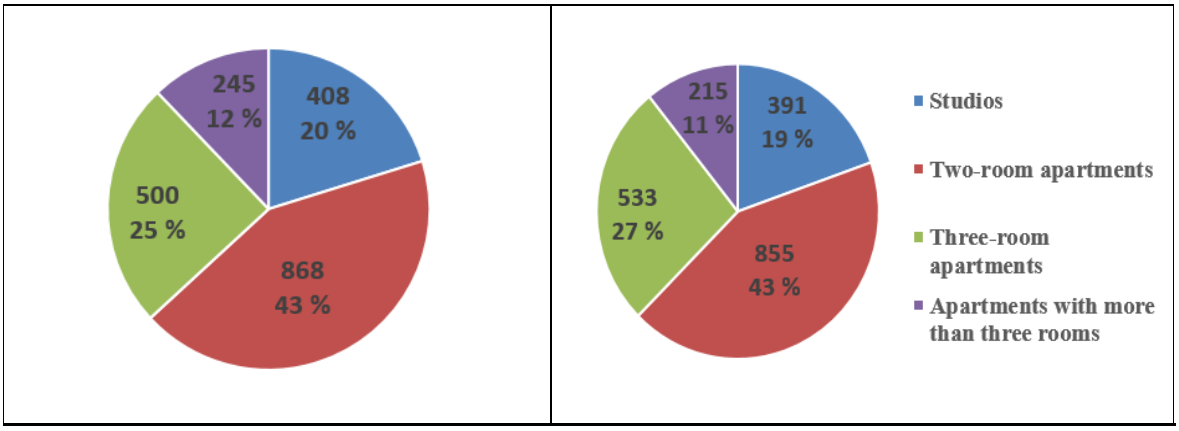
The age of dwellings is measured in the data in years. The newest apartments were built in 2018 and the oldest in 1850. The skewness is very close to zero, so the distribution is very even. The problem with this variable is that the age of the dwelling is not monotonic concerning the price, which is also shown by Pakarinen (2018: 33). Very old dwellings are usually located in a good location, which increases their value, and on the other hand, old dwellings themselves are valued for example because of their history and different architecture. The 400 cheapest dwellings of this study, or about 10 percent of the total data, were built on average in 1971. Therefore, we take the absolute value from 1971, which makes the variable more monotonic. This is illustrated in Figure 10 below.



a) Before processing b) After processing (absolute year as 1971)

Figure 11. The effect of the age of the apartment on its price.

The breakdown by dwelling type for both data sets is illustrated in Figure 11. In total, the pandemic data include 391 studios (pre-pandemic data 408), 855 two-room apartments (868), 533 three-room apartments (500), and 215 dwellings with four rooms or more (245). This reveals that the distribution is very similar in both data sets. To clarify the classification, the number of rooms does not include, for example, a separate bathroom or kitchen. In this case, a studio apartment means a dwelling in which the living room and a single bedroom are combined.



a) Before COVID-19 pandemic b) During COVID-19 pandemic

Figure 12. Division by type of the dwelling.

Table 9 presents the correlation coefficients between the variables. Examining the correlations at this stage of the study is important to observe multicollinearity, which was presented in Section 3.1.4. We can observe that the table supports the theory of hedonic prices, as the variables seem to have a mainly positive effect on price formation. The condition of a dwelling correlates with the debt-free price quite as expected, and an apartment in good condition has a positive effect on the price. Slightly surprisingly, the correlation between the debt-free price of a dwelling in poor condition is correspondingly weaker than the correlation between the debt-free price of a dwelling in a satisfactory condition. Part of the reason for this can be assumed to be the subjectivity of the classification.

Another surprising fact is that the location of the apartment on the ground floor or top floor, as well as the balcony, does not seem to have much effect on the price. The data show that the pure floor level variable is more suitable for modeling, so we only take advantage of this in further analysis. The combination variable for the top floor and the elevator also seems to be insignificant in terms of price, so this is omitted. Furthermore, we continue to include the balcony variable in the modeling, as its importance may increase when we assess differences before and during a pandemic by apartment type. As expected, the balcony and especially the sauna correlate very negatively with the age of the apartment, as their apartment-specific construction has become more common in later decades.

There is a very strong positive correlation between the number of rooms in a dwelling and its floor area (0.875), so in order to avoid the multicollinearity problem, it makes sense to construct regressions according to dwelling types and thus the number of rooms variable will not be used as such in further analyzes.

Table 9: Pearson correlations from all the variables

Pearson correlation	Price	District price €/m2	Area (m2)	Floor	Average income on the area	Apartment age	Number of rooms	Bottom floor	Top floor	Elevator	Top floor and elevator	Good condition	Average condition	Bad condition	Own plot	Sauna	Balcony	Helsinki-1	Helsinki-2
Price	1,000	0,556	0,711	0,161	0,505	0,195	0,512	-0,088	-0,034	0,252	0,084	0,210	-0,185	-0,061	0,261	0,168	-0,091	0,450	-0,450
District price €/m2	0,556	1,000	0,010	0,190	0,652	0,474	-0,107	-0,093	-0,119	0,326	0,058	0,122	-0,126	0,014	0,425	-0,063	-0,266	0,873	-0,873
Area (m2)	0,711	0,010	1,000	0,035	0,162	-0,081	0,875	-0,030	0,036	0,083	0,049	0,078	-0,058	-0,046	-0,019	0,261	0,062	-0,026	0,026
Floor	0,161	0,190	0,035	1,000	0,061	0,047	0,001	-0,593	0,369	0,307	0,455	0,023	-0,026	0,020	0,078	0,004	-0,051	0,158	-0,158
Average income on the area	0,505	0,652	0,162	0,061	1,000	0,347	0,056	-0,035	-0,051	0,187	0,022	0,089	-0,084	-0,010	0,331	-0,041	-0,163	0,507	-0,507
Apartment age	0,195	0,474	-0,081	0,047	0,347	1,000	-0,166	-0,025	-0,007	-0,056	-0,014	-0,090	0,065	0,069	0,291	-0,432	-0,221	0,361	-0,361
Number of rooms	0,512	-0,107	0,875	0,001	0,056	-0,166	1,000	-0,020	0,050	0,024	0,030	0,055	-0,032	-0,050	-0,088	0,214	0,107	-0,116	0,116
Bottom floor	-0,088	-0,093	-0,030	-0,593	-0,035	-0,025	-0,020	1,000	-0,264	-0,132	-0,153	-0,034	0,031	0,004	-0,020	-0,020	0,028	-0,072	0,072
Top floor	-0,034	-0,119	0,036	0,369	-0,051	-0,007	0,050	-0,264	1,000	-0,201	0,588	-0,005	0,006	-0,013	-0,077	-0,002	0,004	-0,107	0,107
Elevator	0,252	0,326	0,083	0,307	0,187	-0,056	0,024	-0,132	-0,201	1,000	0,267	0,068	-0,055	-0,011	0,143	0,128	-0,090	0,283	-0,283
Top floor and elevator	0,084	0,058	0,049	0,455	0,022	-0,014	0,030	-0,153	0,588	0,267	1,000	0,028	-0,016	-0,018	0,008	0,039	-0,040	0,056	-0,056
Good condition	0,210	0,122	0,078	0,023	0,089	-0,090	0,055	-0,034	-0,005	0,068	0,028	1,000	-0,905	-0,234	0,048	0,116	-0,019	0,131	-0,131
Average condition	-0,185	-0,126	-0,058	-0,026	-0,084	0,065	-0,032	0,031	0,006	-0,055	-0,016	-0,905	1,000	-0,149	-0,057	-0,095	0,029	-0,131	0,131
Bad condition	-0,061	0,014	-0,046	0,020	-0,010	0,069	-0,050	0,004	-0,013	-0,011	-0,018	-0,234	-0,149	1,000	0,016	-0,050	-0,004	0,004	-0,004
Own plot	0,261	0,425	-0,019	0,078	0,331	0,291	-0,088	-0,020	-0,077	0,143	0,008	0,048	-0,057	0,016	1,000	-0,062	-0,122	0,377	-0,377
Sauna	0,168	-0,063	0,261	0,004	-0,041	-0,432	0,214	-0,020	-0,002	0,128	0,039	0,116	-0,095	-0,050	-0,062	1,000	0,070	-0,040	0,040
Balcony	-0,091	-0,266	0,062	-0,051	-0,163	-0,221	0,107	0,028	0,004	-0,090	-0,040	-0,019	0,029	-0,004	-0,122	0,070	1,000	-0,222	0,222
Helsinki-1	0,450	0,873	-0,026	0,158	0,507	0,361	-0,116	-0,072	-0,107	0,283	0,056	0,131	-0,131	0,004	0,377	-0,040	-0,222	1,000	-1,000
Helsinki-2	-0,450	-0,873	0,026	-0,158	-0,507	-0,361	0,116	0,072	0,107	-0,283	-0,056	-0,131	0,131	-0,004	-0,377	0,040	0,222	-1,000	1,000

We also measure VIF values for the variables in Table 10, which allows us to better estimate possible multicollinearity. The VIF values do not exceed a limit value of 10, which can be considered a very significant multicollinearity problem. However, some of the variables get a value of about 5, which already indicates possible multicollinearity, so it makes sense to divide the data even more.

Table 10: VIFs for the whole data

Variable	VIF
District price €/m2	6,701
Area (m2)	4,811
Floor level	1,126
Average income on the area	1,903
Apartment age	1,834
Number of rooms	4,661
Elevator	1,295
Good condition	1,110
Bad condition	1,063
Own plot	1,250
Sauna	1,371
Balcony	1,097
Helsinki-2	4,406

4.2.2 Dividing the data regionally

Section 2.3 presents the characteristics of the Helsinki housing market and the specialty of the Helsinki market area in Finland. However, the Helsinki area is immense and there are extensive regional differences in housing prices. This is shown, for example, in the data for this study by a variable indicating the average regional price per square meter, with a maximum value of 8327 euros and a minimum value of 2037 euros. Therefore, the impact of regional differences on house price formation should not be ignored in the modeling.

The data of this study will be divided regionally into two parts, Helsinki-1 and Helsinki-2. Pakarinen (2018: 39-40) makes the division into four parts, but the data of this study are considerably smaller when it is further divided according to the types of dwellings and the time of the pandemic, so the division into only two parts is justified. The division is made according to the zip codes using Statistics Finland's allocation criteria (see Appendix A). Helsinki-1 covers the entire downtown area with old unique buildings and architecture. Besides, most of the major services, schools, administrations, and corporate headquarters are located in this area and public transportation is easily accessible. Geographically, Helsinki-1 is close to the sea, while Helsinki-2 includes more inland areas. In this data, 59% of transactions are from the Helsinki-1 region and 41% from the Helsinki-2 region.

Table 11 shows the differences between the regions in the means of the variables. As can be seen, the difference in the average price is considerable, almost 200 000 euros. Apartments in the city center are slightly smaller, older and on average in better condition. Besides, condominiums more generally have their own plot. Elevators are also considerably more common in the Helsinki-1 area, which may be partly since the dwellings in the Helsinki-2 area are lower-rise according to the floor level variable.

Table 11: Comparison of variables in different regions of Helsinki

	Both areas	**Helsinki-1**	**Helsinki-2**
Price	313 833,55	391 850,35	201 027,40
District price	5 127,34	6 330,15	3 388,17
Area (m2)	59,30	58,72	60,13
Floor level	2,95	3,17	2,64
Average income on area	29 495,37	32 873,28	24 611,17
Apartment age (years)	57,03	65,37	44,98
Number of rooms	2,32	2,23	2,46
Elevator	0,59	0,70	0,42
Good condition	0,59	0,64	0,51
Average condition	0,37	0,31	0,44
Bad condition	0,04	0,04	0,04
Own plot	0,69	0,83	0,48
Sauna	0,15	0,14	0,17
Balcony	0,32	0,23	0,44

5 Results

This chapter presents regression models estimated based on hedonic pricing theory for the COVID-19 pandemic as well as before the pandemic. First, we estimate the hedonic price function (HPF) for the entire dataset using both the linear (level-level) and log-log functions introduced in the Section 3.1.5. Subsequently, the models are divided by apartment type and regionally and the robustness of the models is tested. After all, we create a total of 16 HPFs. In the final modeling, we utilize the log-log function. Furthermore, we present the purpose of the skewness of the distribution. The skewness of the residuals of the models in this study is analyzed, on the basis of which we can assess whether the COVID-19 pandemic has caused imbalances in the Helsinki housing market and thus favored home buyers or sellers.

5.1 Joint regression model

The results of the regressions for the whole data, also divided by COVID-19 pandemic and before the pandemic, are emphasized in Table 12. The models are constructed both linearly and with log-log functions, allowing divergences to be compared both monetary and in relative terms. Both models are highly executable and the independent variables explain the variance of the dependent price variable y well. The value of coefficient of determination (R^2) is high for both models, 0.83 to 0.84 for the linear model and as high as 0.90 to 0.91 for the log-log model. The better explanatory power of the log-log model is not surprising, as this model reduces, for example, the heterogeneity of the model, which is also shown by Pakarinen (2018: 46).

In the models, the age variable has been replaced by an absolute value calculated from 1971. These dwellings are on average the cheapest in the data. This is due, for instance, to the fact that early 70s apartments undergo expensive renovations, such as plumbing repairs. The outcomes of the models are well expected. Furthermore, the results (in terms of valuing different housing features as well) are very similar both before and during the pandemic. With the exception of the variable describing the poor condition of the dwelling, the variables have a mainly positive effect on the price of the apartment and almost all variables are statistically significant at the 1 % level, which is no wonder in the data of several thousand observations. In all linear models, one square meter increases the price of an apartment by approximately 5400 euros, which is a little higher than the average district price of the data (about 5127 euros).

The marginal effect of the district price variable in the entire dataset 50.98 is slightly smaller than the average apartment size (59.30 square meters). It is noteworthy that during the pandemic, the marginal effect is about 56 (log-log model 0.737), whereas, in the pre-pandemic data, the result is just over 46 (0.829). This may indicate that during the pandemic, transactions have focused more strongly on larger dwellings and, on the other hand, housing prices have been more in line with Statistics Finland's zip code data of average district prices.

The elevator is statistically significant only in the log-log model and even gets a negative value in the linear model of the pandemic data. Pakarinen (2018: 45) states that the negative cost effect of the elevator is a possible reason for this. Vainio (1995) also obtains negative values for elevator coefficients in his study, which is suspected to be due to, among other things, an omitted variable bias. In general, in log-log models the elevator seem to increase apartment prices by about 2 percent, which is in line with the findings of Brotherus (2011), for example. The sauna variable, on the other hand, is interesting. The sauna does not obtain statistically significant values in any of the models. Moreover, in the pre-pandemic linear model, the coefficient even gets a negative value. Also in log-log models, the effect is very minimal (less than one percent) and not statistically significant. These findings are contradictory to previous studies such as Brotherus (2011), Huttunen (2009), and Pakarinen (2018) where the positive price effect of the sauna is multiple percent.

There are several reasons for the low significance of the sauna in the modelings. Probably the reason is in the data because in many observations the possible existence of the sauna is stated very vaguely, which leaves it very open to interpretation. In these ambiguous cases, the sauna has been omitted from the observation. On the other hand, now the sauna can be found in the data from 15 percent of the findings, which is in line with, for example, Pakarinen's (2018) study. Besides, the modeling may have an omitted variable bias that affects the results. Furthermore, one possible explanation for the low significance of the sauna is in the changing residential preferences: the own sauna in the apartment is not so highly valued as before and saunas are being built in new apartments less and less. The effect is great, especially in the Helsinki metropolitan area, where prices per square meter are expensive: the space occupying the sauna is preferred for other uses. It will be interesting to investigate whether the sauna acquires statistically significant values in the following models when the material is broken down into smaller parts.

The effect of the balcony on the price of the apartment is about 1-3 percent depending on the model. The results follow well the observations of Brotherus (2011) and Vainio (1995), for example. It is noteworthy that in these models, the balcony has a significantly greater impact on price in the pandemic data (3.3 %) than in the pre-pandemic data (1.3 %).

In all models, one additional floor has a price effect of about 3 percent, and Pakarinen (2018) observes similar results. Even though the condition of the dwelling is a subjective view of the real estate agent, the variables received statistically significant values in almost all estimates. The results are also very expected, a good condition apartment has a price-increasing effect and a poor condition one has a declining effect. A detail to consider is that in the data during the pandemic, a poor classification has a negative effect of more than 8 %, while before the pandemic the result is about -4.5 %. Own plot has a positive price effect of about 5 - 7 %, so the results follow smoothly the observations of Vainio (1995) and Brotherus (2011).

Table 12: Joint regression model (level-level and log-log)

Variable	Whole data (levels)	Std. Error	Whole data (log-log)	Std. Error	Pre-pandemic data (levels)	Std. Error	Pre-pandemic data (log-log)	Std. Error	Pandemic data (levels)	Std. Error	Pandemic data (log-log)	Std. Error
Intercept	-397470,27***	6468,17	0,924***	0,121	-393074,04***	9380,55	0,857***	0,169	-405992,67***	9005,70	0,903***	0,174
District price €/m2	50,98***	1,34	0,782***	0,012	46,26***	1,99	0,737***	0,017	56,04***	1,83	0,829***	0,017
Area (m2)	5401,54***	54,09	0,735***	0,006	5413,29***	75,08	0,745***	0,009	5439,48***	78,79	0,726***	0,009
Floor level	4700,45***	859,22	0,027***	0,004	3846,64***	1248,08	0,027***	0,006	5997,13***	1187,08	0,031***	0,006
Average income on the area	1,58***	0,23	0,160***	0,015	1,94***	0,33	0,196***	0,021	1,26***	0,31	0,131***	0,021
| Age from 1971 |	1378,16***	99,16	0,086***	0,003	1601,95***	144,82	0,090***	0,004	1149,31***	135,25	0,078***	0,004
Elevator	2399,75	3005,61	0,019***	0,006	4249,03	4327,80	0,024***	0,008	-2687,66	4229,01	0,012	0,008
Good condition	29705,62***	2853,27	0,094***	0,005	31853,71***	4166,66	0,101***	0,007	27301,33***	3930,23	0,087***	0,008
Bad condition	-20685,58***	7251,63	-0,066***	0,013	-15803,70	11158,70	-0,045**	0,020	-25299,16***	9519,92	-0,084***	0,018
Own plot	23170,85***	3189,98	0,067***	0,006	23661,84***	4746,73	0,076***	0,008	21666,31**	4326,18	0,056***	0,008
Sauna	-4420,30	4017,38	0,004	0,008	-8898,90	6011,40	0,007	0,011	908,71	5421,85	0,005	0,011
Balcony	12747,99***	3019,17	0,022***	0,006	8756,27**	4417,78	0,013*	0,008	17783,20***	4164,91	0,033***	0,008
R^2	**0,83**		**0,91**		**0,84**		**0,91**		**0,84**		**0,90**	
N	**4015**		**4015**		**2021**		**2021**		**1994**		**1994**	

***** = significant at 1 % level**

**** = significant at 5 % level**

*** = significant at 10 % level**

5.2 Results by region and type of the apartment

Next, we look at how the results change when the data is divided by apartment type and regionally presented in Section 4.2.2. It can be assumed that certain types of dwellings form their own sub-market, for example, studios are particularly popular with investors, which is positively reflected in the prices of these dwellings. The regression models are presented in Tables 13 to 16. All variables are converted to a log-log scale and transactions are divided into studios, two-room apartments, three-room apartments, and dwellings with more than three rooms.

Table 13: Regression models for studios

Studios	Pre-pandemic data				Pandemic data			
Variable	Helsinki-1	Std. Error	Helsinki-2	Std. Error	Helsinki-1	Std. Error	Helsinki-2	Std. Error
Intercept	2,821***	0,577	6,224***	1,214	3,392***	0,480	3,407***	1,110
District price €/m2	0,611***	0,080	0,565***	0,062	0,636***	0,072	0,590***	0,082
Area (m2)	0,600***	0,028	0,336***	0,091	0,581***	0,022	0,286***	0,077
Floor level	0,026**	0,011	-0,048**	0,022	0,028**	0,011	0,013	0,023
Average income on the area	0,176***	0,034	0,002	0,126	0,115***	0,036	0,241**	0,123
| Age from 1971 |	0,034***	0,009	0,059***	0,013	0,026***	0,009	0,068***	0,015
Elevator	0,005	0,014	-0,003	0,024	-0,024	0,015	0,071**	0,028
Good condition	0,103***	0,014	0,120***	0,025	0,067***	0,012	0,072***	0,025
Bad condition	-0,039	0,029	-0,093**	0,046	-0,033	0,023	-0,147**	0,060
Own plot	0,106***	0,022	0,043*	0,024	0,091***	0,022	0,086***	0,026
Sauna	0,026	0,043	-0,084	0,106	0,006	0,051	0,061	0,081
Balcony	0,104***	0,022	-0,018	0,024	0,039**	0,021	-0,020	0,028
R^2	**0,80**		**0,80**		**0,81**		**0,71**	
N	**322**		**86**		**298**		**93**	

***** = significant at 1 % level**
**** = significant at 5 % level**
*** = significant at 10 % level**

The regression models for the studios all give an R-square value of about 0.80, except for the Helsinki-2 pandemic regression model, which is 0.71. In general, however, we can say that the models are accurate enough. In all models, a large proportion of the variables are significant at the 1% level, which is not surprising. The studios are smaller than other types of apartments, so a more limited number of characteristics can be defined for them. Studio apartments make up a large proportion of housing market transactions and there are very few differences or unique details between these dwellings that are more common in larger apartments.

One additional floor level in the Helsinki-1 models has a positive effect of less than 3 percent on the price of the studio, but as an interesting point for Helsinki-2 before the pandemic, the effect is negative, almost 5 percent. This is probably due to the fact that the dwellings in the Helsinki-2 area have fewer floors. Besides, studios are usually located lower, as the apartments on the upper floors are often larger in square meters. Age has a greater positive effect on the price of housing in the Helsinki-2 area. On average, there are more new apartments in the area than in the Helsinki-1 area, which includes the city center, so the result is not surprising. The existence of an elevator becomes a significant variable only in the Helsinki-2 pandemic model, in which case the elevator has a positive effect of about 7 percent on the price of the apartment. Interestingly, before the pandemic, the price effect is even negative, although the variable is not significant in this model.

Differences in condition classifications arise in poorly maintained apartments. As expected, the effect is negative in all models, but this only becomes a significant variable in the Helsinki-2 models. Before the pandemic, the impact is about 9.3 percent, while during the pandemic as high as 14.7 percent. One reason why the variable does not become significant in the Helsinki-1 models is that the apartments in the city center are highly desired and, on the other hand, the studios are easy and inexpensive to renovate. In this case, poor conditions may not be as important as larger apartments, if the location of the apartment is good. The existence of a sauna does not become a significant variable in any of the models, but instead, the balcony has a largely positive effect in the Helsinki-1 models (approximately 10 percent before the pandemic and about 4 percent during the pandemic). Balconies in studios may be appreciated especially because of the extra space they bring when living space is scarce. In Helsinki-2 models, however, the existence of a balcony even has a negative effect, although the coefficients are not significant.

Table 14: Regression models for two-room apartments

Two-room apartments	**Pre-pandemic data**				**Pandemic data**			
Variable	**Helsinki-1**	**Std. Error**	**Helsinki-2**	**Std. Error**	**Helsinki-1**	**Std. Error**	**Helsinki-2**	**Std. Error**
Intercept	0,403	0,470	4,125***	0,570	0,961**	0,441	3,063***	0,674
District price €/m2	0,800***	0,070	0,714***	0,040	0,879***	0,053	0,874***	0,043
Area (m2)	0,671***	0,033	0,478***	0,051	0,674***	0,031	0,315***	0,055
Floor level	0,038***	0,011	0,002	0,012	0,041***	0,010	0,013	0,013
Average income on the area	0,208***	0,039	-0,007	0,056	0,105***	0,029	0,041	0,068
| Age from 1971 |	0,088***	0,009	0,118***	0,008	0,064***	0,008	0,086***	0,009
Elevator	-0,005	0,015	0,056***	0,014	-0,018	0,014	0,030**	0,015
Good condition	0,083***	0,014	0,092***	0,013	0,087***	0,013	0,086***	0,015
Bad condition	-0,003	0,040	-0,027	0,043	-0,046	0,034	-0,144***	0,035
Own plot	0,104***	0,019	0,043***	0,013	0,047***	0,016	0,042***	0,015
Sauna	0,062***	0,021	-0,030	0,020	-0,002	0,020	-0,009	0,021
Balcony	0,034**	0,016	0,006	0,013	0,037***	0,014	0,046***	0,014
R^2	**0,79**		**0,74**		**0,77**		**0,72**	
N	**484**		**384**		**482**		**373**	

***** = significant at 1 % level**
**** = significant at 5 % level**
*** = significant at 10 % level**

For two-room apartments, we get R-squared values for the models from 0.72 to 0.79. Moreover, we can notice that models are not quite as accurate as the studios, but the results are satisfactory. Besides, compared to the studios, we get very similar results in these models. Floor level becomes a significant variable only for Helsinki-1. Age has a greater positive effect on prices in the Helsinki-2 area and there are almost no differences before and during the pandemic. The elevator acts as a significant variable only in the Helsinki-2 models, in which case its positive effect is almost 6 percent. For Helsinki-1, the coefficients are negative but not significant.

The poor condition of the dwelling has a very negative effect during the pandemic in the Helsinki-2 model, more than 14 percent, otherwise the coefficients are not significant. At the general level, we can therefore conclude that during the pandemic, buyers of one-bedroom apartments have sought to acquire better-quality housing, especially in the Helsinki-2 area. The balcony has a positive effect (about 3.5 to 5 percent) in all models and is also a significant variable except for modeling Helsinki-2 before the pandemic. Interestingly, the sauna becomes a significant variable only in the pre-pandemic model of Helsinki-1, when the price effect it brings is more than 6 percent. This is in line with previous studies on the effects of sauna. Otherwise, in two-room models, the sauna has a negative price effect, but the coefficients are not significant.

Table 15: Regression models for three-room apartments

Three-room apartments	Pre-pandemic data				Pandemic data			
Variable	**Helsinki-1**	**Std. Error**	**Helsinki-2**	**Std. Error**	**Helsinki-1**	**Std. Error**	**Helsinki-2**	**Std. Error**
Intercept	0,327	0,665	3,824***	1,076	-0,396	0,638	2,399**	1,035
District price €/m2	0,696***	0,095	0,931***	0,057	0,977***	0,081	0,929***	0,054
Area (m2)	0,827***	0,054	0,257**	0,117	0,906***	0,058	0,239**	0,102
Floor level	0,031*	0,018	0,039**	0,018	0,033**	0,016	0,015	0,017
Average income on the area	0,255***	0,058	-0,053	0,095	0,066	0,054	0,104	0,099
| Age from 1971 |	0,067***	0,014	0,093***	0,014	0,057***	0,013	0,089***	0,012
Elevator	0,007	0,023	0,017	0,020	-0,015	0,024	0,033*	0,019
Good condition	0,090***	0,021	0,141***	0,021	0,079***	0,022	0,125***	0,019
Bad condition	-0,056	0,071	-0,053	0,048	-0,094*	0,054	-0,123**	0,060
Own plot	0,124***	0,027	0,027	0,020	0,096***	0,026	0,044**	0,020
Sauna	0,026	0,026	0,041	0,032	0,010	0,024	0,028	0,027
Balcony	-0,007	0,022	-0,018	0,020	0,035	0,022	-0,018	0,019
R^2	**0,82**		**0,77**		**0,81**		**0,77**	
N	**262**		**238**		**293**		**240**	

***** = significant at 1 % level**

**** = significant at 5 % level**

*** = significant at 10 % level**

The R-squared values of the three-room dwelling regressions follow well the previous modeling, being between 0.77 and 0.82. Also, the results appear to be similar in some respects to those for studios and two-room apartments. The age of the apartment has a greater positive effect on the price in the Helsinki-2 area. The elevator will only become a significant variable in the Helsinki-2 pandemic data, albeit only at the 10 % level. The floor of the apartment seems to have quite similar coefficients in both the Helsinki-1 and Helsinki-2 areas. The variable now also becomes a significant variable in Helsinki-2 before the pandemic in the data (but not in the data during the pandemic), which serves as an indicator that three-room dwellings are valued more on the upper floors.

The poor condition of the apartment only becomes a significant coefficient in both pandemic models. The apartment in good condition, on the other hand, has a slightly smaller positive price effect than before the pandemic. Another interesting detail is that the balcony and sauna are not significant variables in any of the models, and the price effect for the balcony is even negative in most of the models. It would seem that the valuation of these variables focuses on smaller dwellings, which is not surprising, especially for the balcony, due to the limited living space available for these apartments.

Table 16: Regression models for apartments with more than three rooms

More than three rooms	Pre-pandemic data				Pandemic data			
Variable	Helsinki-1	Std. Error	Helsinki-2	Std. Error	Helsinki-1	Std. Error	Helsinki-2	Std. Error
Intercept	-0,503	1,061	1,931*	1,148	-0,468	1,155	-3,578*	2,069
District price €/m2	0,716***	0,130	1,022***	0,093	0,896***	0,140	0,858***	0,130
Area (m2)	0,983***	0,062	0,654***	0,123	0,819***	0,082	0,836***	0,157
Floor level	0,032	0,029	-0,024	0,032	0,044	0,029	-0,013	0,037
Average income on the area	0,244***	0,074	-0,103	0,123	0,164**	0,076	0,499**	0,244
| Age from 1971 |	0,047**	0,019	0,144***	0,018	0,069***	0,025	0,141***	0,025
Elevator	0,043	0,040	0,040	0,036	0,051	0,051	-0,036	0,047
Good condition	0,104***	0,036	0,105***	0,032	0,134***	0,038	0,050	0,042
Bad condition	-0,224*	0,114	0,122	0,180	-0,092	0,127	-0,080	0,095
Own plot	0,215***	0,057	0,149***	0,038	0,129**	0,052	0,039	0,045
Sauna	-0,002	0,041	-0,093**	0,046	0,017	0,042	-0,085*	0,055
Balcony	-0,004	0,036	-0,108***	0,036	0,035	0,040	-0,001	0,046
R^2	**0,85**		**0,81**		**0,84**		**0,76**	
N	**140**		**105**		**112**		**103**	

***** = significant at 1 % level**
**** = significant at 5 % level**
*** = significant at 10 % level**

The R-squared values of the regressions for dwellings with more than three rooms are between 0.76 and 0.85. We think the results are surprisingly good compared to the fact that these apartments are sold less and, on the other hand, these dwellings have the greatest variation in terms of characteristics. Besides, apartments that contain a different number of rooms, unlike in other models, are classified in this group. The estimate of the floor area of the dwelling increases as the number of rooms increases, as does the district price. This finding follows Pakarinen's (2018) study. An interesting observation is that the district price estimate exceeds number 1 only in the model describing Helsinki-2 before the pandemic, which means that only in this model apartments have been sold at a higher price than Statistics Finland's regional data show.

In these models, the poor condition of the apartment only becomes a significant coefficient in the pre-pandemic Helsinki-1 model, in which case the negative price effect is even more than 22 percent. For Helsinki-2, the effect is even positive, probably due to the subjective nature of the classification, but the variable is not significant. At its best, the apartment's own plot has a positive price effect of more than 20 percent. This is significantly higher than for smaller dwellings. Larger apartments usually have a higher monthly maintenance charge, as this is often determined by the floor area of the apartment. Combined with the rental plot, the costs would be remarkably high, so the result is understandable. For the sauna and balcony, the results are very similar to those for the three-room apartment models. The price effect of the sauna is even remarkably negative in the Helsinki-2 models and significant, as is the balcony in the modeling of the same area before the pandemic.

5.3 Testing the model robustness

In Section 4.2.1, we presented the Pearson correlation table and calculated the VIF values between the variables to be able to detect possible multicollinearity. We found that it is worthwhile to divide the data into smaller parts in order to alleviate the problems posed by the phenomenon. This section focuses on identifying possible heteroscedasticity in our models. For this, we first utilize a visual evaluation of the scatterplots (residuals and fitted values), after which we perform Breusch-Pagan testing (Breusch et al. 1979) on each model to conduct a deeper analysis. Below are as an example two models of scatterplots, two-room apartments in the Helsinki-2 area before the pandemic and apartments with more than three rooms in the Helsinki-2 area before the pandemic. Except for individual outliers, we can observe that the pattern of larger dwellings is more irregular, indicating possible heteroscedasticity in modeling. Pakarinen (2018: 58-59) confirms that the phenomenon is common in the case of larger dwellings due to their versatile characteristics and unique price formation.

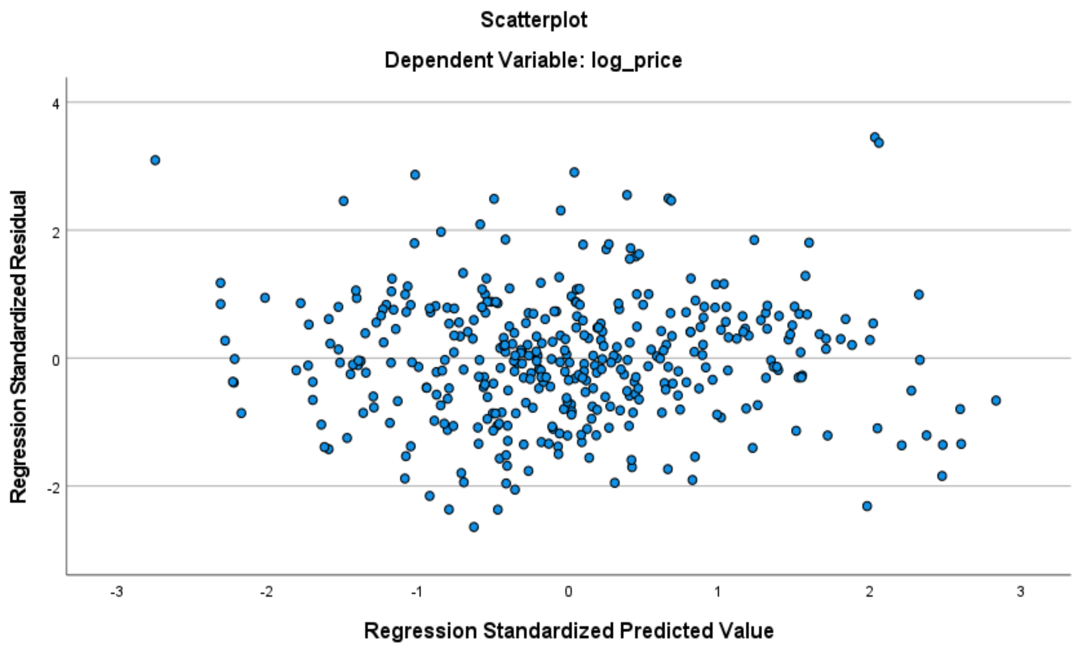


Figure 13. Scatterplot for two-room aparments (Pre-pandemic data, Helsinki-2).

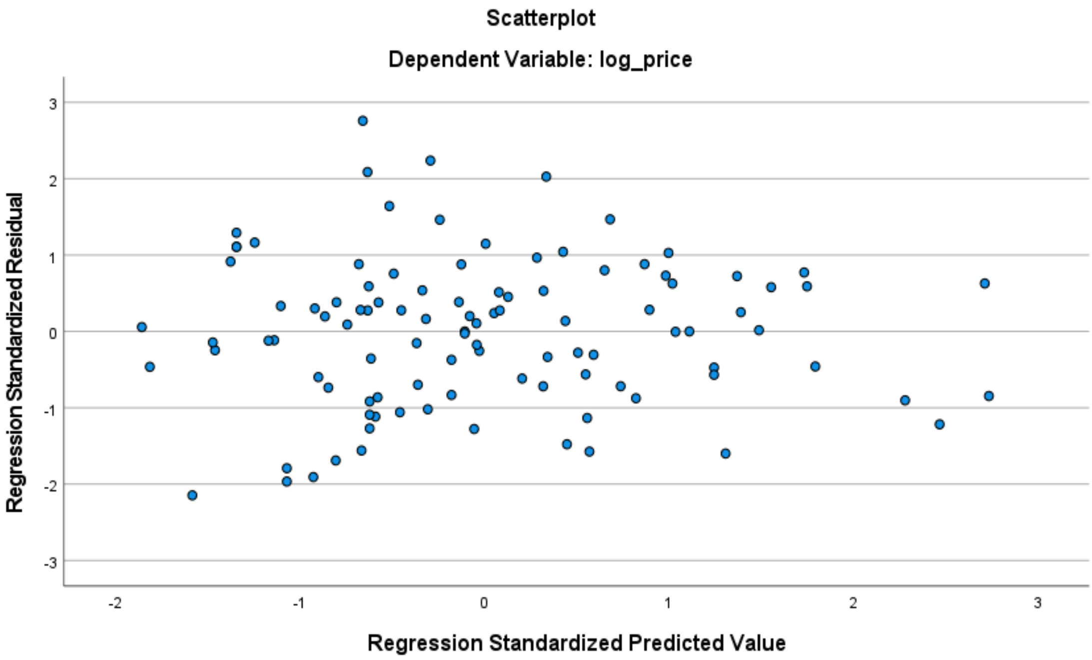


Figure 14. Scatterplot for apartments with more than three rooms (Pre-pandemic data, Helsinki-2).

We aim to detect the non-constant variance of the random variable, in other words, possible heteroscedasticity, using Breusch-Pagan testing for each model. The test results are illustrated in Table 17. Based on the results, dwellings appear to be more homogeneous the smaller they are, while there is more heterogeneity for larger apartments. This also supports Pakarinen's (2018: 59) results and claims about the heterogeneity of larger dwellings: such apartments are more difficult to model due to the diverse variations in their characteristics. Furthermore, there is more heteroscedasticity present in the downtown area, which is not surprising, as there is more variation in housing characteristics in the city center compared to the sub-urban area.

Table 17: Breusch-Pagan test results for the model heteroscedasticity

		Pre-pandemic data	Pandemic data
Studio	Helsinki-1	no	no
	Helsinki-2	no	no
Two-room apartment	Helsinki-1	no	yes
	Helsinki-2	no	no
Three-room apartment	Helsinki-1	yes	yes
	Helsinki-2	no	no
Four or more rooms	Helsinki-1	yes	no
	Helsinki-2	yes	yes

yes = significant at 1 % level

no = not significant at 1 % level

The results are not surprising, as heteroscedasticity is a common problem in studies that model the housing markets. Modeling can be improved by utilizing, for example, semi-parametric function forms instead of parametric functions, as in Pakarinen's (2018) study. However, even in this study, heteroscedasticity cannot be completely eliminated. Based on the results, the parametric function form, in this case, the linear function, is a sufficient starting point to evaluate the effects caused by the COVID-19 pandemic, and therefore it is utilized as an estimation method in the further analysis as well.

5.4 Skewness of the residuals

Regression residuals receive relatively little attention in academic research and are assumed to satisfy predefined parametric assumptions such as normality. Instead, the standard econometric analysis focuses heavily mainly on the parameter estimates of the regression equation. Traditional modeling is more interested in the marginal effects of explanatory variables than in the distribution assumptions of residuals. However, stochastic modeling methods are intended to investigate the non-normality of regression residuals in the research area, where inefficiency arises from the distribution of residuals. These are divided into stochastic noise and inefficiency (Pakarinen, 2018: 78).

In the context of the housing market, non-normal residuals may be due to uncontrolled factors. Pakarinen (2018: 79) states that these factors can also have opposite effects so that they would be able to cancel each other out. However, an asymmetric distribution, in other words, the skewness of residuals, indicates that either market participant, seller, or buyer, has the advantage in the market. Besides, in this case the market is inefficient. The price formation of dwellings varies according to the characteristics and location of the dwelling which makes it possible that either market participant has an advantage in a certain submarket (Pakarinen 2018: 79). In this study, the skewness of the residuals is examined on the basis of the residuals of the OLS regression models presented in Section 5.2.

5.4.1 Distribution skewness

When applying the linear model, it should be thought from a theoretical point of view that the conditions give reliable estimates. In the estimation, the residual terms are assumed to be homoscedastic as well as non-correlated with each other. If the residual terms are independently and identically distributed with a zero mean, the OLS estimator becomes the maximum likelihood estimator (Pakarinen, 2018: 81). Linear models are often estimated using a normal distribution supported by a central limit theorem. Residuals are distributed symmetrically on both sides of the zero mean, otherwise, the distribution is skewed. In positive skewness, the right tail of the distribution is longer than the left, giving most residuals values smaller than the mean zero. In negative skewness, the situation is the opposite, in which case most of the residuals are larger than the mean zero (Pakarinen, 2018: 82). The normal distribution, as well as the skewness of the distribution, are illustrated in Figure 14.

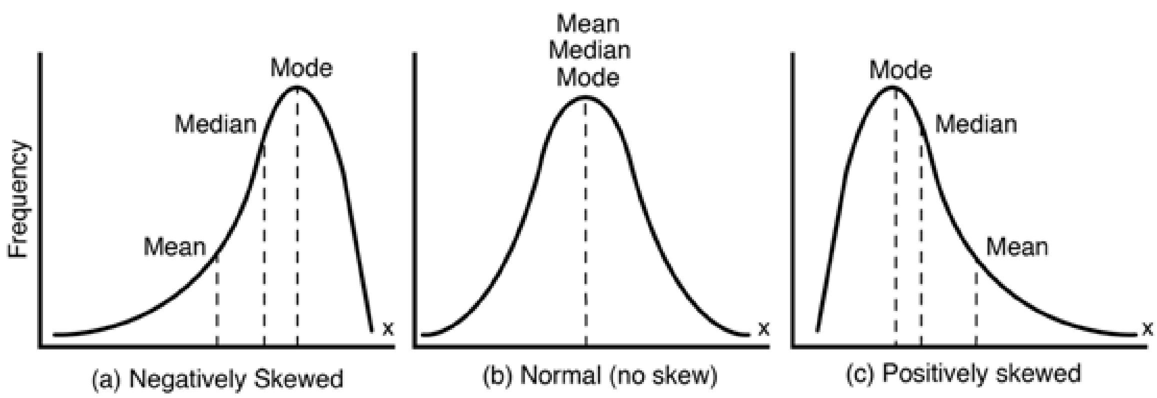


Figure 15. Distribution skewness.

Source: Faria, Oliveira & Pimentel-Junior, 2015

How should the skewness of the residuals be viewed from the context of the housing market? In a negative skewness, buyers pay a premium for the apartment in relation to its characteristics and the residuals are positive on aggregate level. However, there are apartments on the market that have been sold at significantly lower than median prices. We can also draw a conclusion that in a positive skewness the situation is the opposite: the residuals are negative and the actual prices are lower than the efficient price frontier.

To measure the regression residuals, sample moment testing should be utilized in our study. Pakarinen (2018: 83) confirms that in this case, the second and the third sample moments $m_2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$ as well as $m_3 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3$ are calculated around the mean $\bar{x}$ of the sample. Then we are able to calculate test statistics $\sqrt{b_1}$ and the sign of this test statistic determines whether the distribution of residuals is negatively or positively skewed:

$$\sqrt{b_1} = \frac{m_3}{m_2^{3/2}} \tag{16}$$

5.4.2 Measuring the skewness of the OLS regression residuals

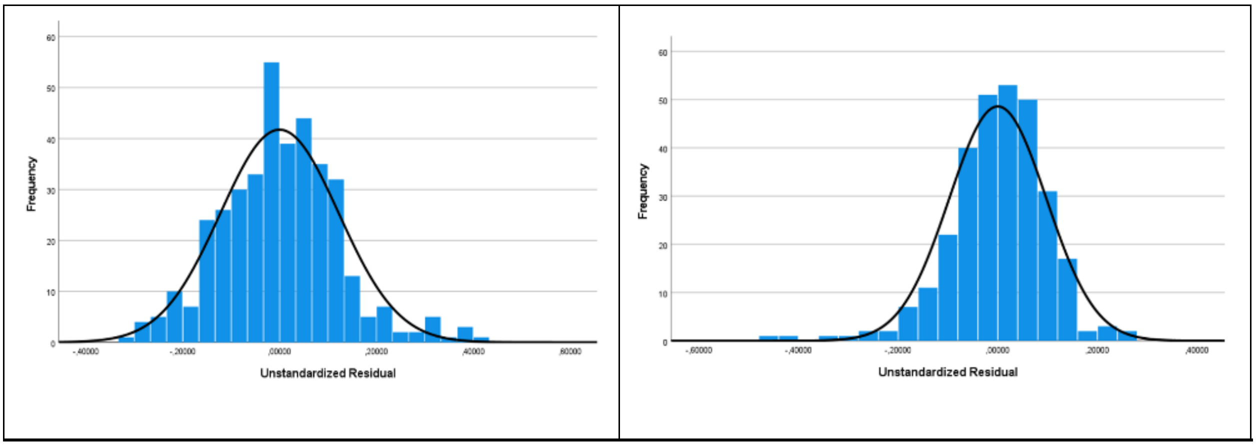
The residual statistics for the OLS regressions in this study are presented in Table 18, broken down by pre-pandemic time and COVID-19 -pandemic time. We can see that before the pandemic, half of the models have a positive skewness, while during a pandemic, as many as seven of the eight models have negative skewness. The high positive value of the residual reflects the fact that the seller has received a larger amount of money from the apartment than the model would predict with the dwelling's characteristics. However, it should be noted that the price is also affected by factors that are outside our modeling. For example, high noise pollution could be negatively reflected in the price of an apartment, while beautiful views have a positive price effect.

The table also presents the kurtosis of the residuals and the high value of the kurtosis reflects that a larger proportion of the residuals are close to the mean and the tails of the distribution are short (Pakarinen, 2018: 86). For example, in the Helsinki-1 area of the pandemic model, three-room apartments receive a high kurtosis, where the value is particularly affected by a few very cheaply sold apartments compared to the efficient price frontier.

Table 18: OLS regression residual statistics

Pre-pandemic data	Region	St. Dev	Min	Max	Skewness	Kurtosis
Number of rooms						
Studio	**Helsinki-1**	0,11	-0,35	0,44	0,12	0,60
	Helsinki-2	0,09	-0,36	0,23	-0,51	1,73
Two-room apartment	**Helsinki-1**	0,14	-0,49	0,43	-0,03	0,73
	Helsinki-2	0,12	-0,33	0,40	0,33	0,71
Three-room apartment	**Helsinki-1**	0,15	-0,55	0,53	-0,05	1,35
	Helsinki-2	0,15	-0,50	0,45	-0,03	0,21
Four or more rooms	**Helsinki-1**	0,18	-0,37	0,64	0,84	1,69
	Helsinki-2	0,15	-0,33	0,42	0,10	0,01
Pandemic data		**St. Dev**	**Min**	**Max**	**Skewness**	**Kurtosis**
Studio	**Helsinki-1**	0,10	-0,44	0,27	-0,82	2,64
	Helsinki-2	0,10	-0,28	0,24	-0,07	0,29
Two-room apartment	**Helsinki-1**	0,13	-0,58	0,36	-0,46	2,18
	Helsinki-2	0,13	-0,49	0,33	-0,34	0,85
Three-room apartment	**Helsinki-1**	0,15	-0,84	0,59	-0,57	6,19
	Helsinki-2	0,14	-0,38	0,36	-0,07	0,13
Four or more rooms	**Helsinki-1**	0,16	-0,56	0,54	-0,50	2,09
	Helsinki-2	0,19	-0,59	0,52	0,08	0,82

In some of the models, the skewness of the residuals is much clearer, and we present two examples of these distributions in Figure 15. Appendix C contains other interesting observations.



a) Two-room apartments (Pre-pandemic, Helsinki-2) b) Studios (Pandemic, Helsinki-1)

Figure 16. Examples of the regression residual distributions.

D'Agostino (1970) demonstrates a transformation that allows us to calculate critical values for test statistics $\sqrt{b_1}$ following the *N(0,1)* distribution:

$$
\begin{gathered}
Y = \sqrt{b_1}\{\frac{(N+1)(N+3)}{6(N-2)}\}^{1/2} \\
\beta_2 = \frac{3(N^2+27N-70)(N+1)(N+3)}{(N-2)(N+5)(N+7)(N+9)}\}^{1/2}, \\
W^2 = -1 + \{2(\beta_2 - 1)\}^{1/2} \\
\delta = 1/\sqrt{logW} \\
\alpha = \{\frac{2}{W^2 - 1}\}^{1/2}
\end{gathered}
\tag{17}
$$

In the equation, *N* means the size of the sample, whereby the Z-statistic following *N(0,1)* is obtained as follows when $N \geq 8$ (D,Agostino, 1970; Pakarinen, 2018: 84):

$$
Z = \delta \log[Y/\alpha + \{(Y/\alpha)^2 + 1\}^{1/2}] \tag{18}
$$

The critical values for test statistics are then 1.28 at 10% significance level and 1.96 at 5 % level. The critical values for each model are specified in Table 19. The results show that at a significant level of 5 %, three out of eight, or 37.5 %, represent skewed residuals in the pre-pandemic model, which follows the observations of Pakarinen (2018: 90) quite closely. In the pandemic models, the corresponding results are as high as five out of eight, or 62.5 percent.

Table 19: Test results for skewness

Pre-pandemic data	Region	√ b1	Z-stat
Number of rooms			
Studio	**Helsinki-1**	0,12	0,88
	Helsinki-2	-0,51	-1,96**
Two-room apartment	**Helsinki-1**	-0,03	-0,27
	Helsinki-2	0,33	2,64**
Three-room apartment	**Helsinki-1**	-0,05	-0,33
	Helsinki-2	-0,03	-0,16
Four or more rooms	**Helsinki-1**	0,84	4,11**
	Helsinki-2	0,10	0,44
Pandemic data		**√ b1**	**Z-stat**
Studio	**Helsinki-1**	-0,82	-5,76**
	Helsinki-2	-0,07	-0,27
Two-room apartment	**Helsinki-1**	-0,46	-4,14**
	Helsinki-2	-0,34	-2,70**
Three-room apartment	**Helsinki-1**	-0,57	3,95**
	Helsinki-2	-0,07	-0,45
Four or more rooms	**Helsinki-1**	-0,50	-2,18**
	Helsinki-2	0,08	0,34

**** = significant at 5 % level**

*** = significant at 10 % level**

Looking first at pre-pandemic models, it can be seen that positive skewness is much more strongly present than in the pandemic models. We can observe that positive skewness is particularly strong in the case of large dwellings, which is also supported by the results of Pakarinen (2018: 88-89). According to Pakarinen (2018), this is due to the unique characteristics of large apartments and their numerous different combinations, which makes it more difficult to assess the formation of the price, leading to a situation where majority of the transactions are below the estimated effective price frontier. In the case of studios in the pre-pandemic data, the model of Helsinki-2 is negatively skewed, while Helsinki-1 gets a slightly positive value. Pakarinen (2018: 89) makes the same observation, which is explained by the fact that the rental market has been particularly hot in sub-urban areas. Helsinki-2 contains a lot of areas, but they are close to the city center and have good transport connections, so these are the apartments that tenants want. In addition, apartments are cheaper, resulting in a lower price-to-rent ratio and higher profits for investors. However, investors are strict about the price they pay. Although at the aggregate level, prices appear to be above the efficient price front in the Helsinki-2 area, the values of skewness show that there have also been individual very affordable studios on the market, which are sure to attract investors.

In the case of two-room apartments, the situation is the opposite and Helsinki-2 gets a positive value, which is significant at the 5% level. The reasons for this are probably ambiguous. Helsinki-2 is a very large area and also includes quite expensive regions close to the city center. Considering purely regional factors, the characteristics of such dwellings are quite diverse, which affects modeling, and the variables do not necessarily reflect enough variation in the explanatory variable. Furthermore, two-room apartments are not as popular with investors as studios, which means that two-bedroom apartments are used more in owner-occupied housing. In this case, some home buyers may even pay an extra price for the apartment if there is a very attractive dwelling on the market. In the case of positive skewness, such transactions have also taken place in the market.

Interestingly, in the pandemic models, residual values are in many respects opposite to those in pre-pandemic models, and almost all are negatively skewed. For example, apartments with more than three rooms in Helsinki-1 receive a negative value at the 5% significance level, so the market seems to have reversed during the pandemic for these apartments. For two-room apartments, the effect is similar. Furthermore, for three-room apartments in the Helsinki-1 area, the high kurtosis value of the residuals should be taken into account: there appear to be individual observations in the data that differ clearly from the average prices, but the residuals are generally close to the mean.

The results are also noteworthy for studios. The Helsinki-1 region has a considerable negative skewness at the 5% significance level, while in the pre-pandemic model the result is positive. In the Helsinki-2 area, on the other hand, the skewness before the pandemic is very negative, but during the pandemic, the value is close to zero and there does not appear to be a significant imbalance in the market. The highly negative skewness value indicates that there are not many transactions significantly above the median price, but there are studios sold at a price significantly lower than the median price. In this case, we can conclude that apartment buyers have had good opportunities to find studios for sale during the COVID-19 pandemic that are for sale at an extremely affordable price. The same phenomenon does not exist for the Helsinki-2 area. This may be partly explained by the high demand for housing and the fact that people have moved out of the urban area during the pandemic, resulting in more efficient price formation of these dwellings.

The rental market has been in difficulty during the pandemic and supply has increased significantly as short-term rental housing (such as Airbnb apartments) has started to be rented for long-term use. The uncertain situation in the rental market in this respect certainly also reflects the behavior of investors in the market and on the other hand, many may have ended up selling the apartment on a fast schedule, which will lower the transaction price.

6 Discussion & Conclusions

The main purpose of this study is to fill the gap in the academic research and to investigate whether the COVID-19 pandemic has favored home buyers or sellers. The study is limited to the Helsinki housing market and block of flats, excluding new apartments. Furthermore, we aim to utilize hedonic modeling and descriptive analysis to determine how the COVID-19 pandemic has affected people’s living conditions and preferences. Examination of the main research question extends and utilizes Pakarinen's (2018) methods of residual skewness, which allows us to determine whether the COVID-19 pandemic has caused information asymmetry in the Helsinki housing market. Pakarinen is the first to study the skewness of the residuals in the in the context of Finnish housing market, which is supplemented by this paper.

The COVID-19 pandemic has had a significant impact on the housing market globally, but various pandemics have had an effect on the housing market throughout the world history, as demonstrated by Francke et al. (2021) and Wong (2008). The initial shock to the housing market in the spring of 2020 was very severe around the world, as shown by, among others, Yörük (2020), D’Lima et al. (2020), Tanrıvermiş (2020), Ionașcu (2020), & Huang et al. (2020) and the situation in Helsinki is no exception, although the market recovered very quickly supported at global level by, for instance, Zhao's (2020) paper.

As a sub-research question in this study, we address how the COVID-19 pandemic has affected people’s living preferences. With the pandemic, teleworking has increased significantly and, on the other hand, strict restrictions have reduced people’s consumption, with money being invested in their own well-being and thus in housing. This is supported by statistics showing that a record number of dwellings were sold in 2020 and, on the other hand, that people's desire to buy a home is at a record high (PTT, 2021; OSF, 2021b). In general, we can say that the COVID-19 pandemic as a whole has had a stimulating effect on the Helsinki housing market, especially in terms of demand, which has led to a lack of supply and a significant reduction in housing marketing times (see Etuovi.com, 2021).

One of the effects of the coronavirus pandemic on people’s living preferences can be considered the need for additional space. This is supported by statistics showing a significant increase in sales of detached houses, as well as accelerated trade in holiday homes (see e.g. PTT, 2021; KVKL, 2021). The skewness analysis of the residuals shows that the effect is also reflected some extent in Helsinki's apartment buildings, but seems to be limited regionally. Before the pandemic, apartments with more than three rooms in the Helsinki-1 area are very strongly skewed to the right (positive skewness), but during a pandemic, the situation is the opposite and the skewness turns to the left. The results are significant at the 5% level.

The strong negative skewness shows that during the pandemic, there have been apartments in the Helsinki-1 area in both the three-room apartments and in the models of larger apartments, the price of which is significantly cheaper than the median of the models. On the other hand, there are hardly any transactions that are considerably more expensive than the median price in the estimations. In this case, buyers have had the opportunity to find very affordable apartments on the market. There are explicable reasons for this situation, although this is somewhat contradictory to the fact that demand for housing has been strong and supply low, in which case price formation could be expected to maximize. First, the pandemic increased unemployment in Finland at an early stage, affecting about 200 000 people (see Brotherus, 2020a). Moreover, people's wealth naturally decreases considerably, in which case the old standard of living may not be maintained. This is particularly reflected in large dwellings, which have high maintenance costs and fees. Then, the apartment may be forced to sell, even if the price does not correspond to the full market price.

In the Helsinki-2 region, or sub-urban regions, the same effect is not observed. Hence, home owners may have moved from the Helsinki-1 area to a cheaper apartment in the Helsinki-2 area. Furthermore, we can also conclude that buyers of an apartment seeking additional space have either bought, for example, a detached house or a terraced house, or moved completely to another city outside Helsinki. The latter is supported by the fact that the demand for housing during the COVID-19 pandemic has also strengthened considerably in neighboring cities of Helsinki, such as Porvoo (see PTT, 2021).

The results of our regression models also allow us to analyze how certain more detailed residential preferences or dwelling-specific characteristics have been favored during the COVID-19 pandemic. It should be noted that we cannot make universally valid interpretations simply by analyzing the coefficients of the regressions, but the results provide an indication of what characteristics are required of dwellings during the pandemic in addition to the extra living space.

Overall, the results show that during the pandemic, people have wanted to buy housing in better condition than before the pandemic, or at least avoided housing in poor condition to the extent that their negative price impact is much greater during the pandemic. There may be many reasons for this, but one reason may be that when people have had more wealth available to invest in housing on aggregate level, good quality is thus valued. Second, investors often buy housing in poor condition, as such housing has a higher return potential after renovation. During the pandemic, the data used in this study suggest that the share of dwellings bought by investors could be reduced, as the number of homebuyers for owner-occupied housing increased sharply during the pandemic. On the other hand, investors often seek to take advantage of transactions without real estate agents when acquiring dwellings, which, of course, do not appear in this study.

Differences between coefficients can also be found by housing type. The results show that for small apartments (studios as well as two-room apartments), the value of various "luxury characteristics", such as an own balcony and, to some extent, a sauna, has increased. The same effect cannot be interpreted for large dwellings. For example, a balcony may also indicate the need for living space previously considered in the study: for small dwellings, the balcony provides significantly more living space and is available at its best all year round.

The main research question of this study addresses the asymmetries caused by the COVID-19 pandemic in the Helsinki housing market. In Pakarinen's (2018: 90) study, 40 percent of the residuals of sub-market regressions are skewed. Pakarinen's (2018) study can be considered proportional to the pre-pandemic data of this study. In this paper, 37.5 percent of the sub-market regression residuals before the pandemic show skewness, so the results follow very closely Pakarinen's (2018) findings. In the pandemic data, 62.5 percent of the regression residuals are skewed, so there is a big difference in the results and because of this we can state that the COVID-19 pandemic has affected the balance of buyers and sellers in the Helsinki housing market.

The model of studio apartments in the Helsinki-1 area before the pandemic is positively skewed, which, however, is not a statistically significant result. During the pandemic, the situation is the opposite and the distribution is remarkably negatively skewed, which is also statistically significant at the 5% significance level. In the Helsinki-2 area, the effect is not so obvious. The models of studios in the Helsinki-1 area thus have a similar effect to the theory we presented earlier about the situation of large dwellings. There have been studios with a price significantly lower than the median price of the models. Instead, very expensive apartments have been sold less. So, based on our estimation, homebuyers have had opportunities to find very cheap dwellings. The situation is partly due to the same reasons as for large dwellings: people have moved away from the center as teleworking has increased, and layoffs and unemployment have forced them to sell their homes.

There are lower prices for apartments in the Helsinki-2 area, which means that mortgage payments are also lower, and in this case, the unstable state of the labor market is not immediately reflected in the area. On the other hand, the demand for housing has been strong during the pandemic and our research shows that the number of people living alone in Helsinki is constantly growing and thus the popularity of small dwellings (see e.g. OSF, 2019b). Robust demand may have been stronger in the Helsinki-2 region during the pandemic, which has led to clearer price formation. Pakarinen (2018: 89) confirms this stating that especially due to the activity of investors during the normal time in the sub-urban areas, there is also higher competition in these areas and through this, housing has a clearer price formation. Furthermore, migration from the Helsinki-1 area is likely to be more strongly directed to the Helsinki-2 area than, conversely, also to studios, which contributes to the results of the models.

On the other hand, the studios are popular with investors. The rental market has been labile and uncertain during the pandemic and supply has increased much as short-term rental apartments have been rented for a long time usage, which could have affected the investors' behavior. Problems in obtaining good tenants may have led to investors having to sell their apartments on the market, which may have affected the results of our models.

According to our analysis, the phenomenon is very similar for two-room apartments, but unlike studio apartments, the model of the Helsinki-2 area during the pandemic is also negatively skewed at the 5% significance level, while before the pandemic the situation is the opposite. Two-room apartments are often inhabited by small households and single people, so we interpret that the skewness of residuals is caused by very much the same factors as in the case of studio apartments. The uncertain economic situation has led to the availability of remarkably low-cost apartments in the market, although at the aggregate level prices are slightly higher than the median. However, significantly overpriced one-bedroom apartments have not been sold on the market.

In summary, we can say that, in general, the COVID-19 pandemic has affected all housing types in the Helsinki housing market in a very similar way. All of the models that are significant at the 5% significance level are negatively skewed, which is particularly emphasized for studios as well as large dwellings. In this case, the prices are on average slightly above the effective price frontier, but high above the median prices of the models, almost no dwellings have been sold. Instead, there have been significantly cheaper dwellings than the median prices, which has provided buyers with good opportunities to find affordable housing. Prior to the pandemic, the situation is partially contrary, with 66 percent of models at the 5% significance level showing positive skewness with home sellers having had the opportunity to obtain even significant over prices for their apartments.

6.1 Limitations of the study

A significant limiting factor in our research consists of the data from this study. Two separate data sets have been collected for the study from the website Asuntojen.hintatiedot.fi for the periods 5/2019 - 12/2019 and 5/2020 - 12/2020. Only this database has been used in the study, so only a minority of all transactions in the Helsinki area are included in the modeling. Not all real estate agents can be found on this site. There are no transactions made without real estate agents in the modeling either. If the thesis is to be made more comprehensive, data should be collected, for example, from the Finnish Tax Administration's transfer tax data, which would be very challenging. Besides, the data is updated with a delay, as a result of which, for example, the data illustrating the corona pandemic may contain observations in which the transaction has already taken place before the outbreak of the pandemic in Finland.

Our data is divided regionally into only two areas, when, for example, Pakarinen (2018) utilizes four different submarkets. The number of observations in our study are quite limited. If the material were divided into even more sub-markets, in addition to the fact that it is also divided into housing types and according to the pandemic situation, there would be too few observations for some of the models. Thus, to obtain more accurate research results, we should acquire more transaction data, which would only be possible by utilizing more databases or waiting for more transactions to be generated. Besides, the location of the dwelling is described in this study at the zip code level. It would be possible to describe the location in much more detail, as at street level, but this would require more comprehensive data.

It should also be noted that heteroscedasticity is a common problem in housing market modeling studies, which is highlighted when using linear methods as in this study. The models in this study are also partially heterogeneous, as shown by Breusch-Pagan tests and scatterplot analysis. Furthermore, the variables used in the study cause their own limitations. For example, a variable describing the condition rating of an apartment is the real estate agent's subjective view of the condition of the apartment that may be distorted. In addition, in several observations, the balcony of an apartment may mean either a large glazed balcony, a roof terrace, or a small French balcony, although the variable is treated equally in the modeling. Moreover, our variables do not take into account all the characteristics of dwellings, which significantly affects the results of the study.

6.2 Further research

This study has several potential topics for further research. First, the research could be continued by applying frontier estimation techniques from the area of econometric efficiency analysis to assess market inefficiencies. Pakarinen (2018) utilizes the StoNED method (Kuosmanen et al. 2012) in his research, which could be used in this study as well. The methods would allow us to quantify how much inefficiency the COVID-19 pandemic has caused in the market by apartment type in monetary terms, which would popularize the study to a larger audience.

The study utilizes linear modeling using OLS regressions. The problem with linear models in particular is heteroscedasticity. The relationship between housing price and characteristics is rarely monotonic, so it would be natural for research to use more flexible semi-parametric forms of function in estimating the hedonic price function in this study as well, although linear methods are very commonly used in the housing market context. Pakarinen (2018) utilizes the convex nonparametric least squares method (CNLS), which provides more reasonable results than linear modeling.

Data on the effects of the COVID-19 pandemic in the Finnish housing market are becoming more and more available, so the study could be continued over time. In that case, it would be possible to assess whether the effects of the pandemic are only very ephemeral, as the time period used in this study of just over six months is relatively short. On the other hand, the effects of a pandemic would also be interesting to study on a larger scale geographically. The study could be carried out, for example, to cover all developing cities in addition to the Helsinki metropolitan area, in particular Turku and Tampere, and to compare the results regionally. On the other hand, the study could also be carried out in larger rural cities, allowing us to assess whether the COVID-19 pandemic has exacerbated the housing market situation in these areas or vice versa, the possibilities in this regard are very limitless. Moreover, this study is based on actual transaction prices. If we also had information on housing asking prices, it would be possible to make a more in-depth analysis of how well the asking prices correspond to the actual transaction prices and to estimate the impact of the pandemic in this respect.

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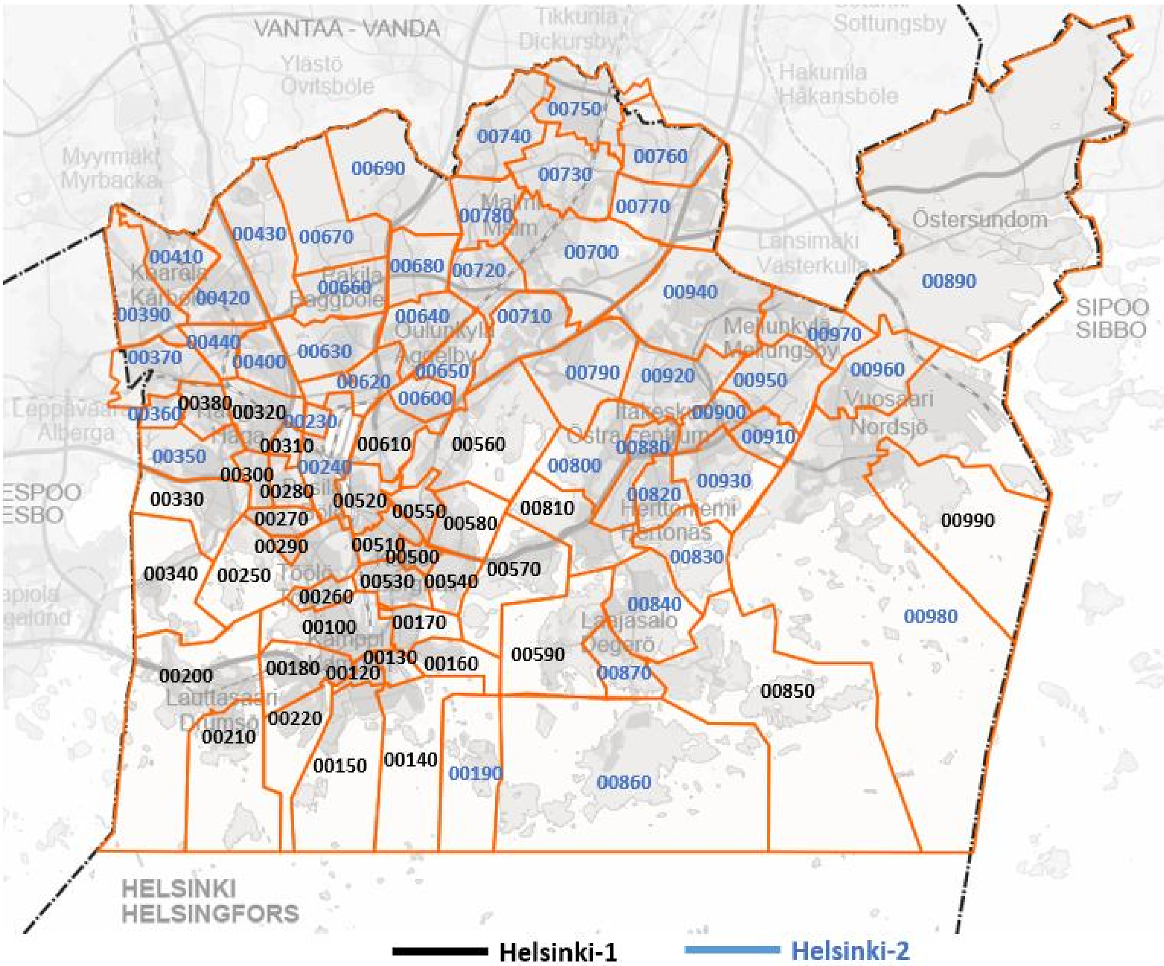
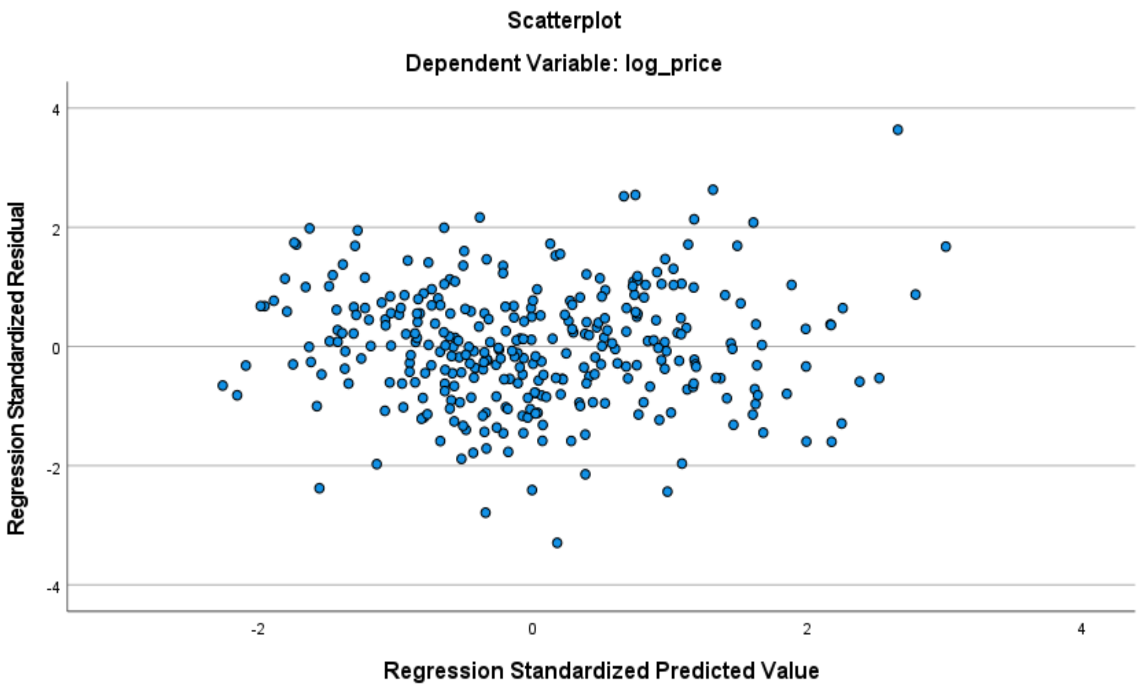
Appendix A: Zip code based data division

Helsinki-1	00100, 00120, 00130, 00140, 00150, 00160, 00170, 00180, 00200, 00210, 00220, 00250, 00270, 00280, 00290, 00300, 00310, 00320, 00330, 00340, 00380, 00500, 00510, 00520, 00530, 00540, 00550, 00560, 00570, 00580, 00590, 00610, 00810, 00850, 00990
Helsinki-2	All other zip codes in Helsinki.

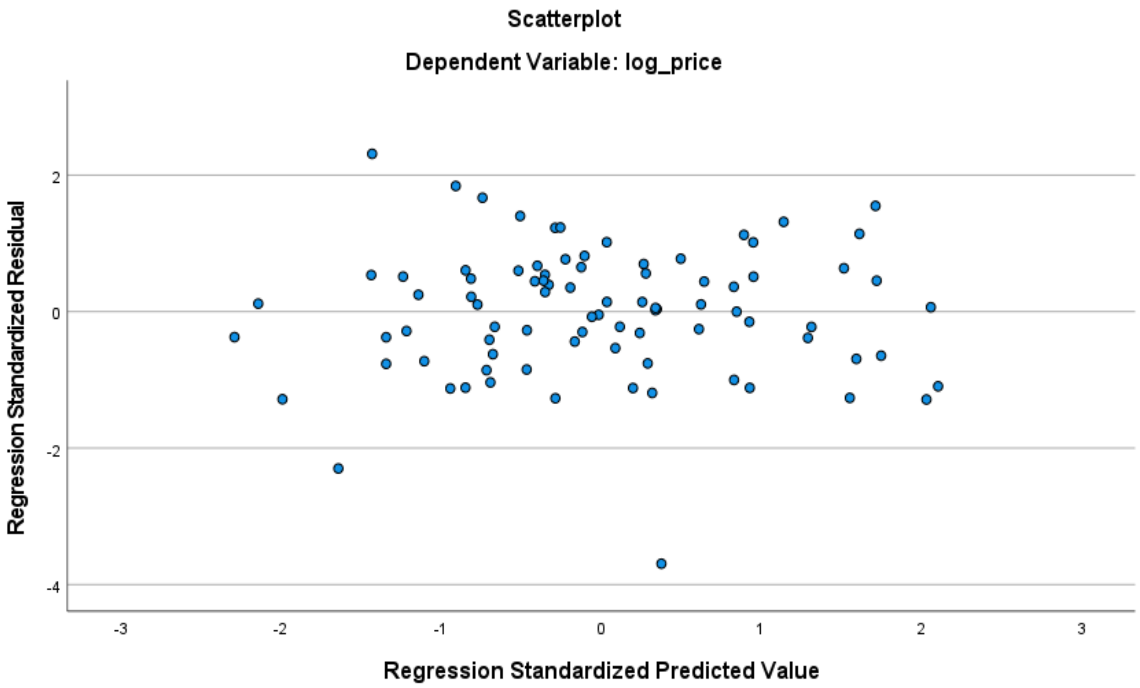


Helsinki postal code areas and regional division

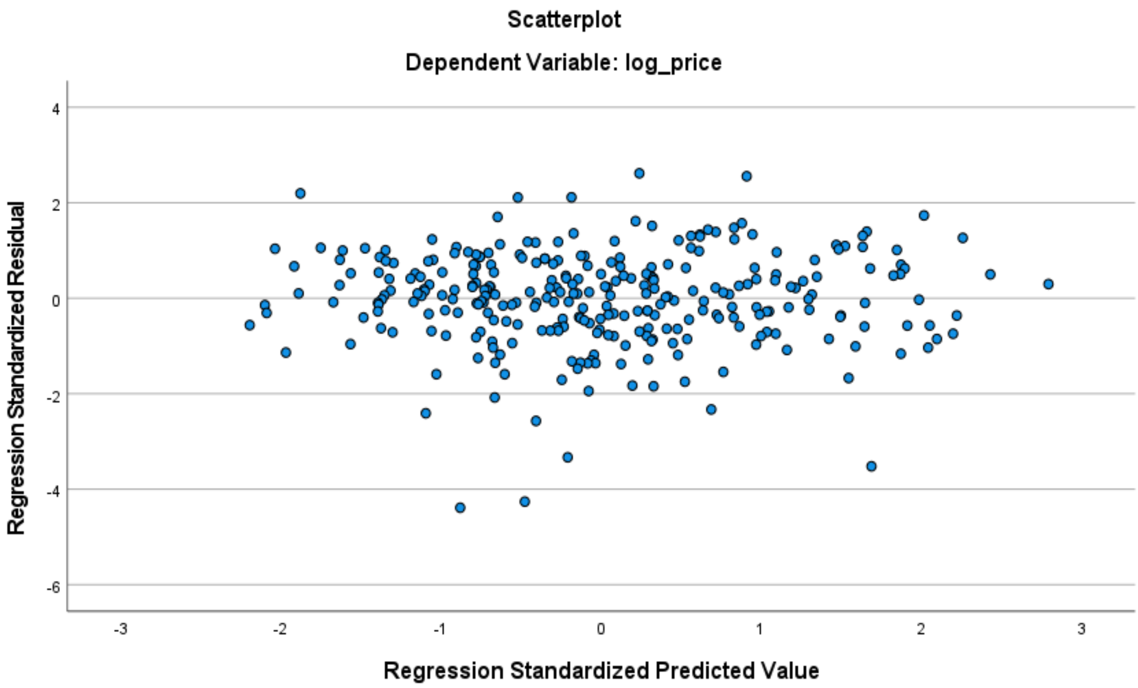
Appendix B: Residuals and fitted values



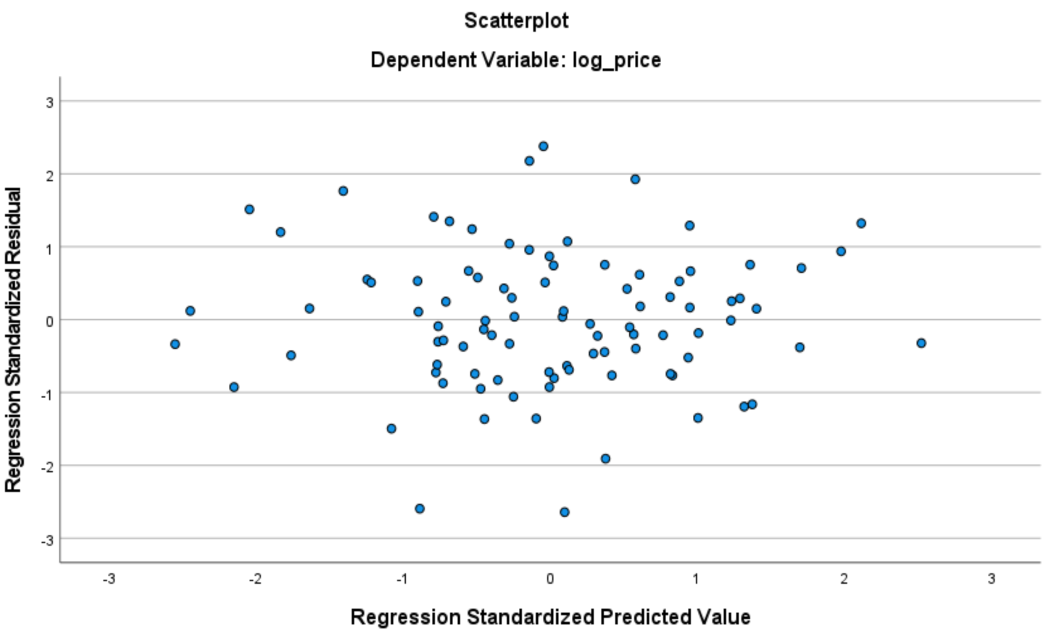
Scatterplot for studios (Pre-pandemic data, Helsinki-1)



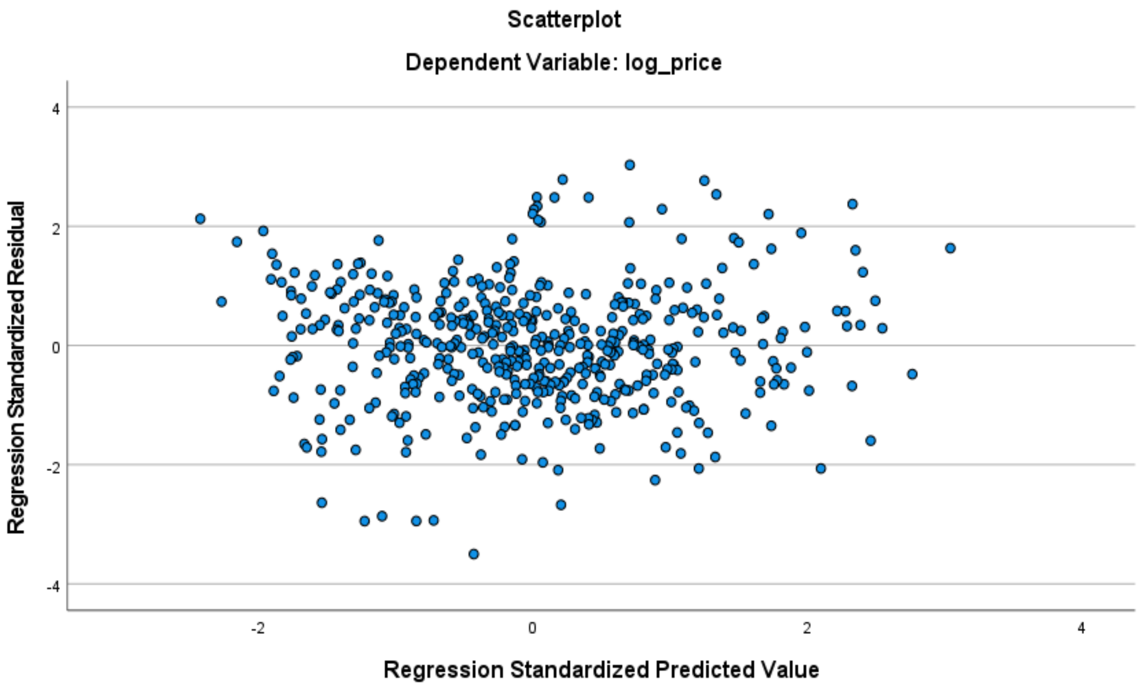
Scatterplot for studios (Pre-pandemic data, Helsinki-2)



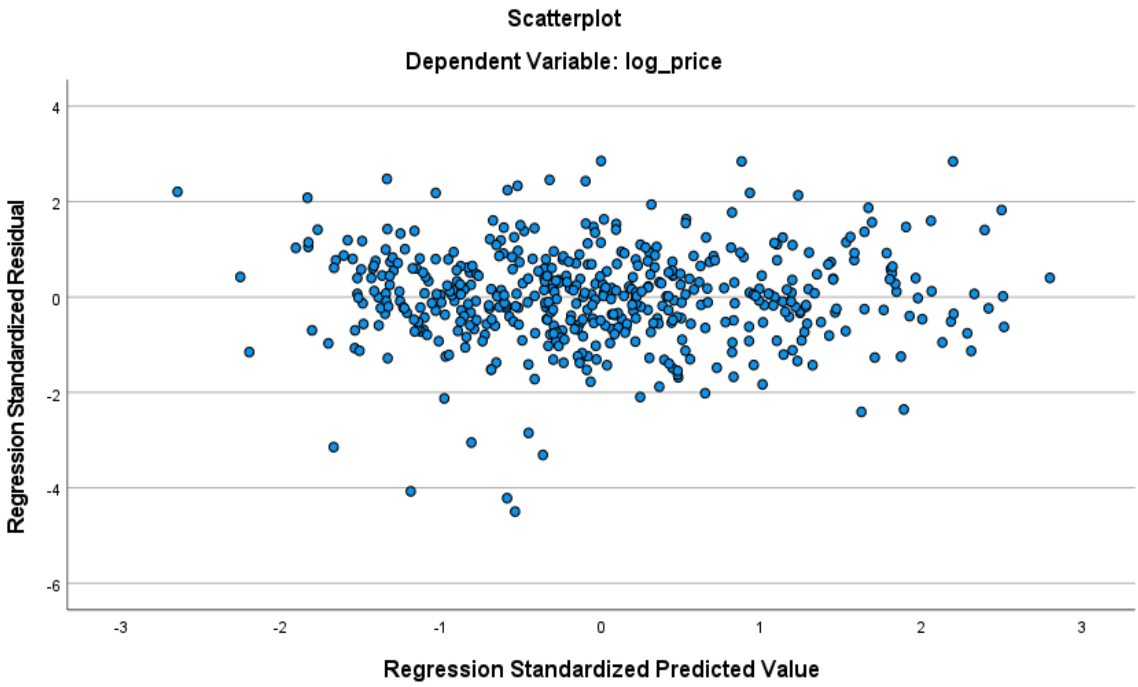
Scatterplot for studios (Pandemic data, Helsinki-1)



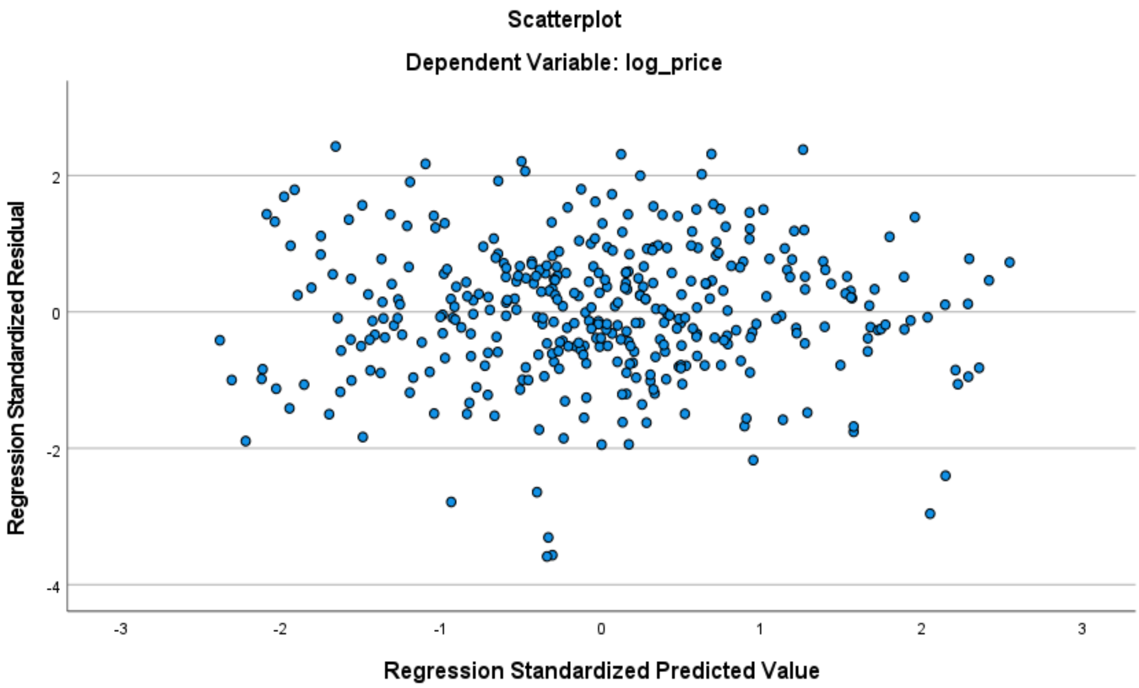
Scatterplot for studios (Pandemic data, Helsinki-2)



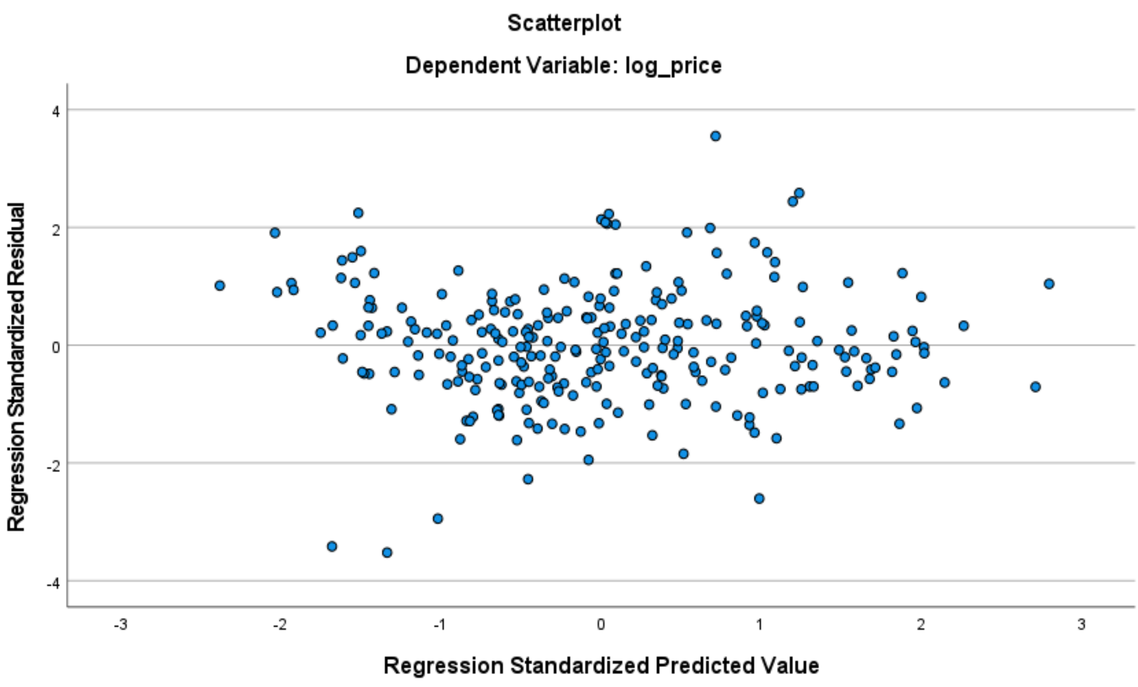
Scatterplot for two-room aparments (Pre-pandemic data, Helsinki-1)



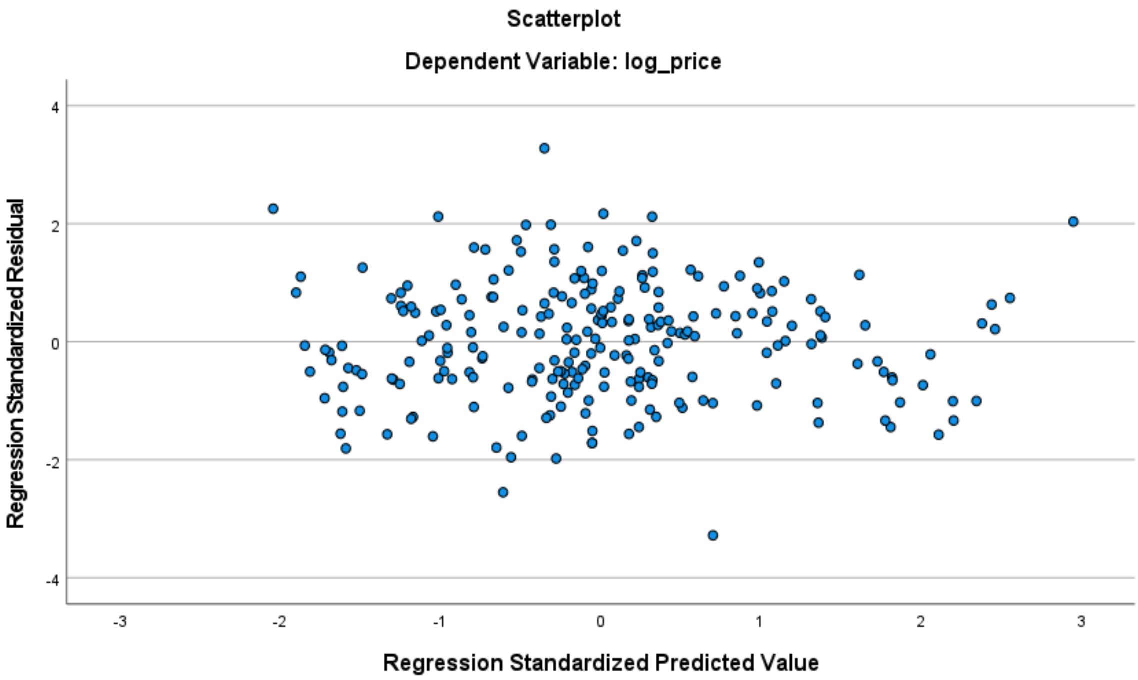
Scatterplot for two-room aparments (Pandemic data, Helsinki-1)



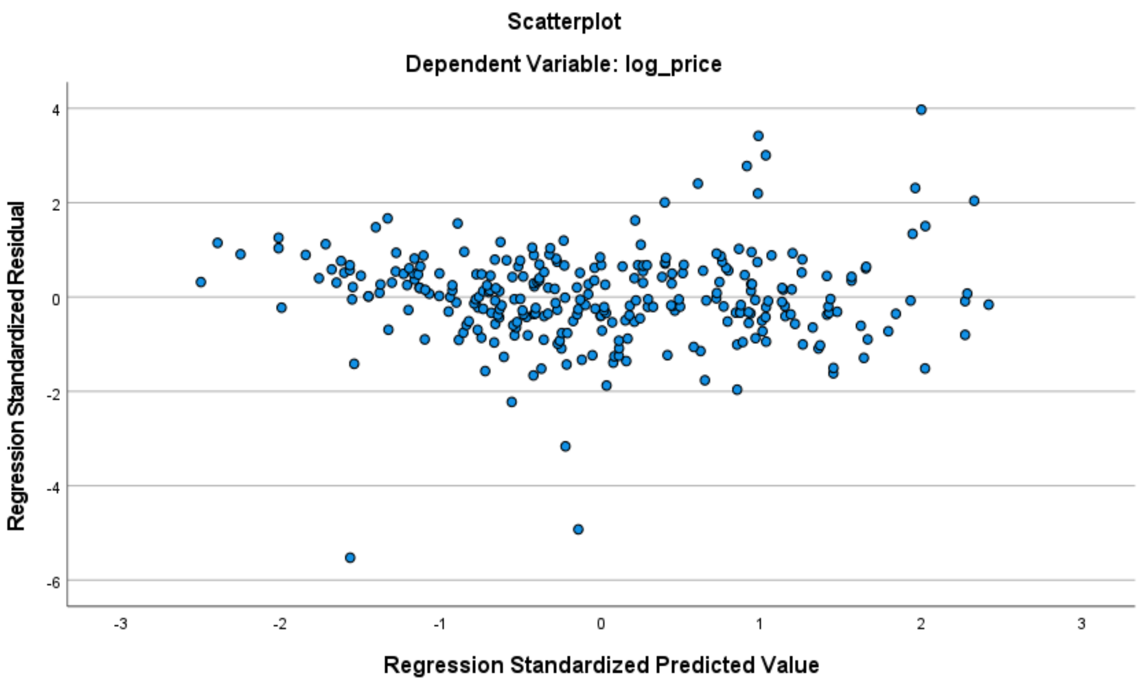
Scatterplot for two-room aparments (Pandemic data, Helsinki-2)



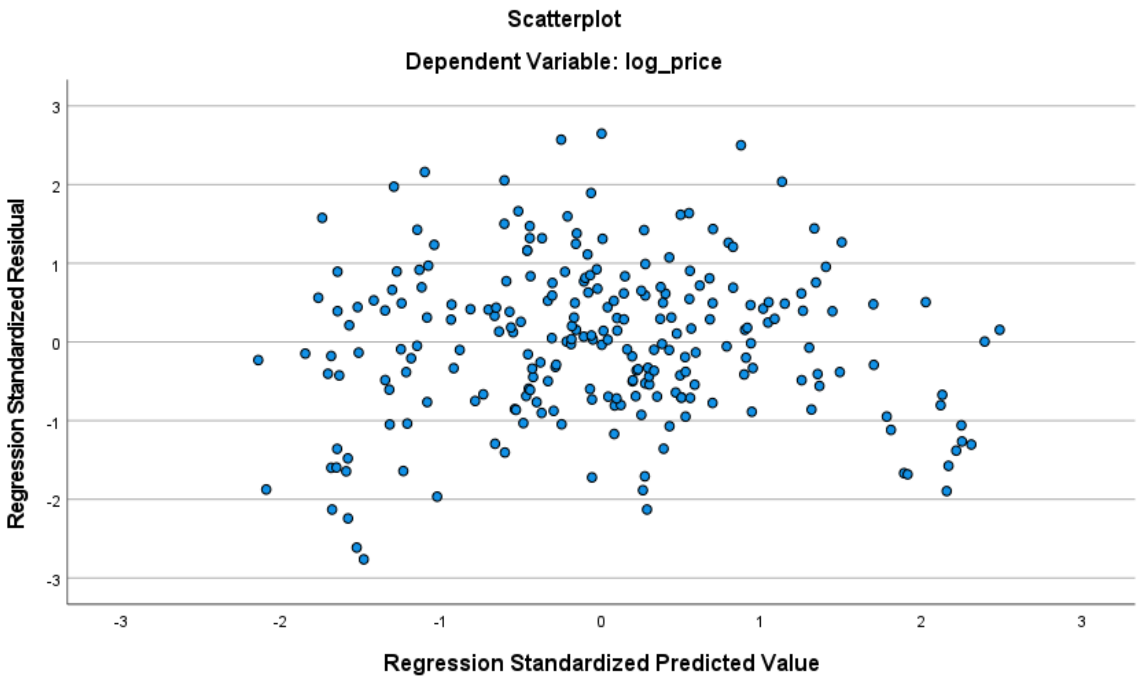
Scatterplot for three-room aparments (Pre-pandemic data, Helsinki-1)



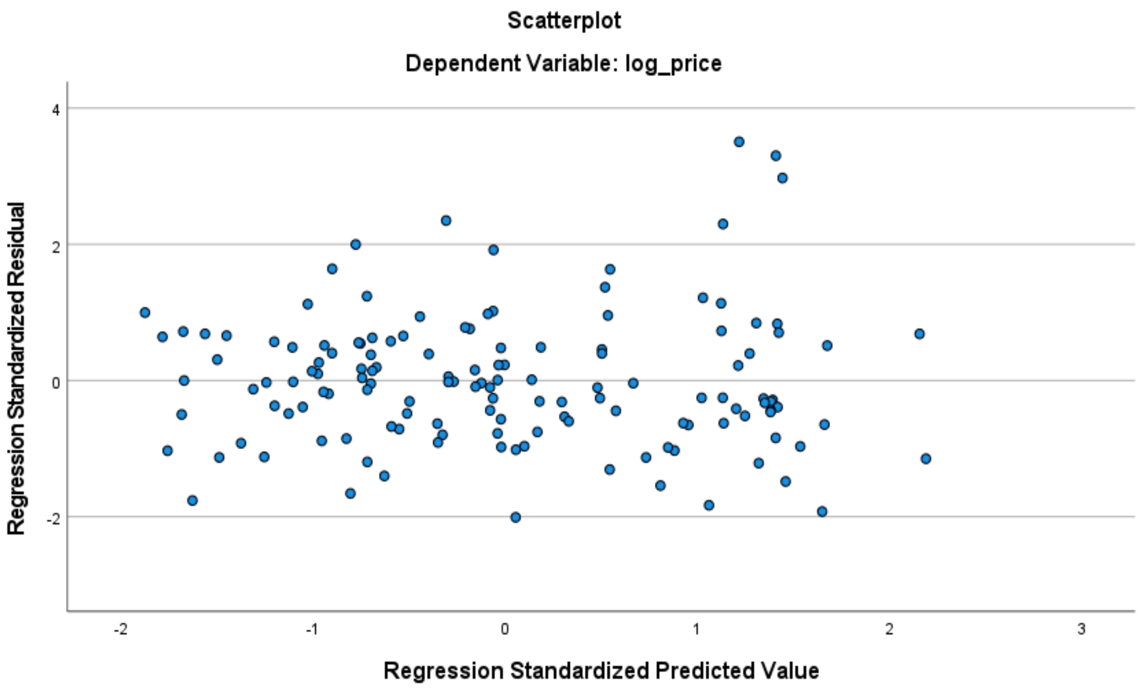
Scatterplot for three-room aparments (Pre-pandemic data, Helsinki-2)



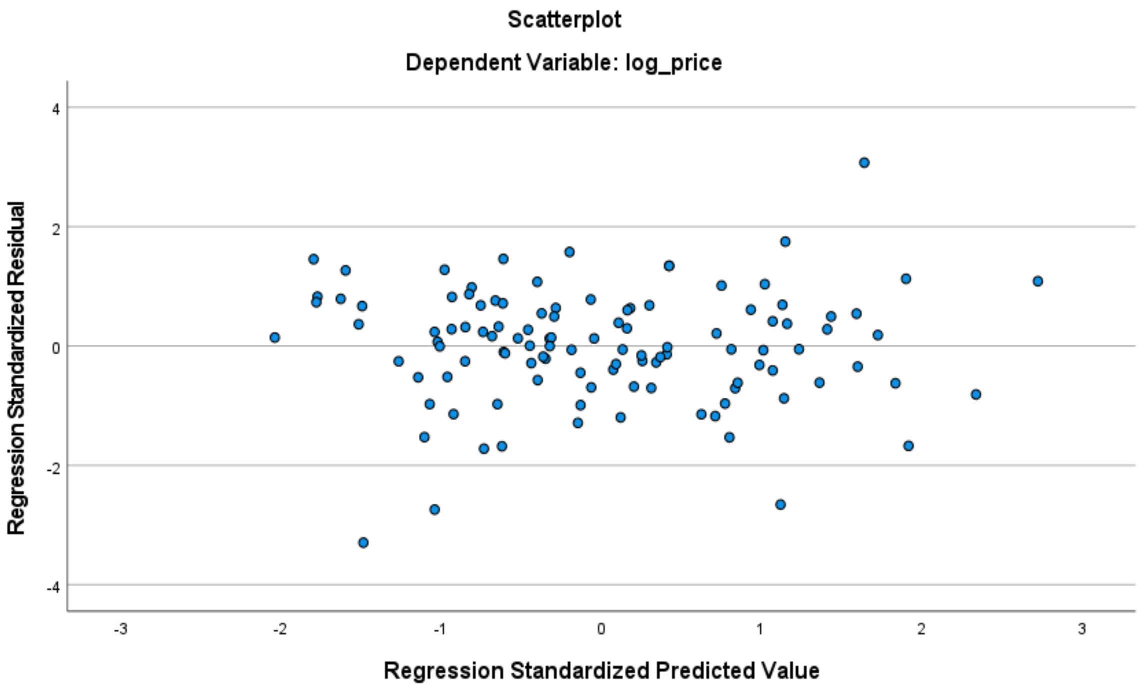
Scatterplot for three-room aparments (Pandemic data, Helsinki-1)



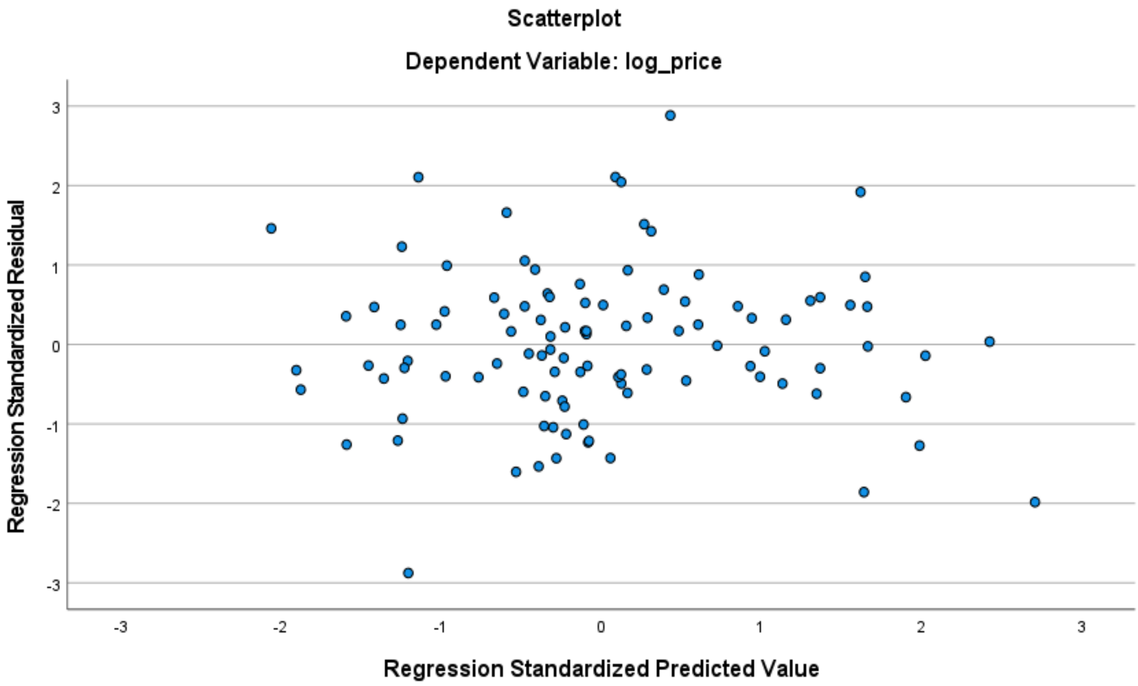
Scatterplot for three-room aparments (Pandemic data, Helsinki-2)



Scatterplot for apartments with more than three rooms (Pre-pandemic data, Helsinki-1)

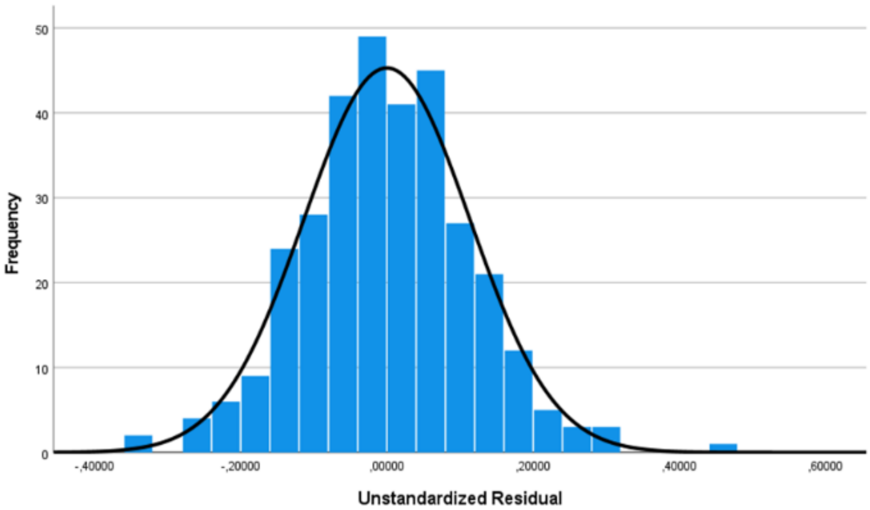


Scatterplot for apartments with more than three rooms (Pandemic data, Helsinki-1)

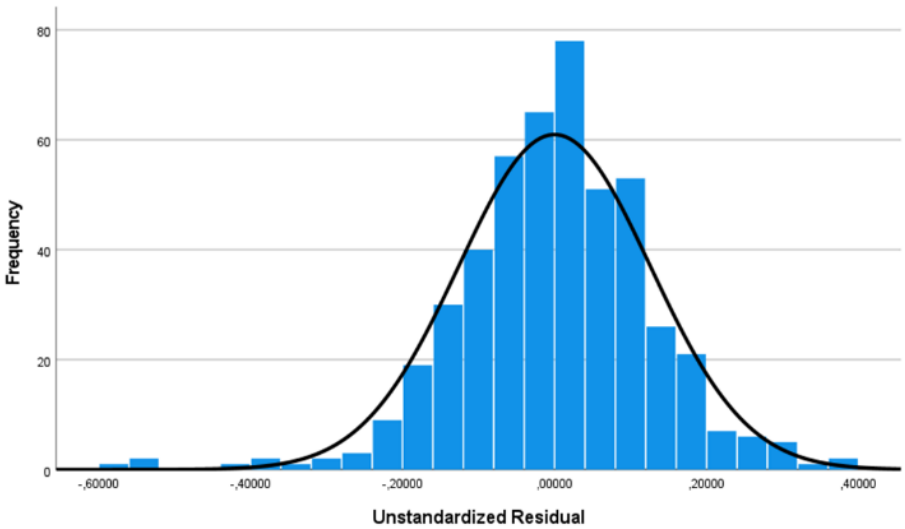


Scatterplot for apartments with more than three rooms (Pandemic data, Helsinki-2)

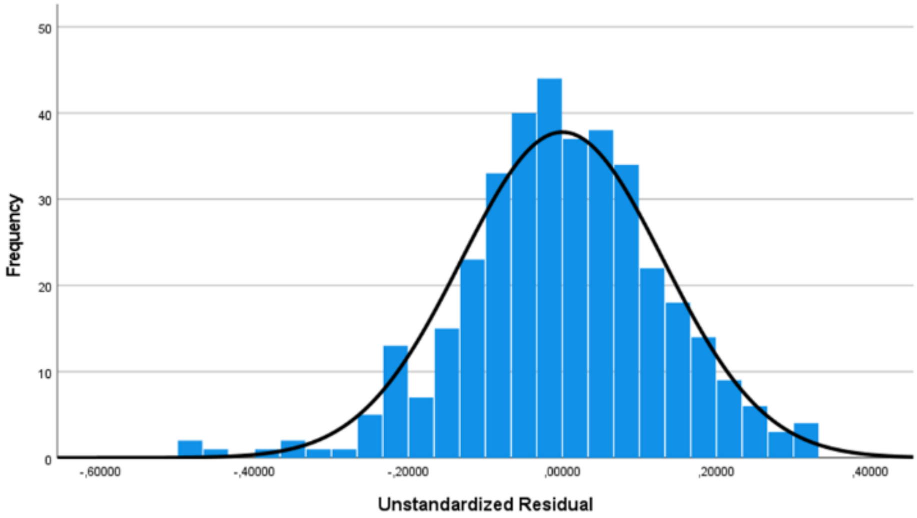
Appendix C: Residual distributions



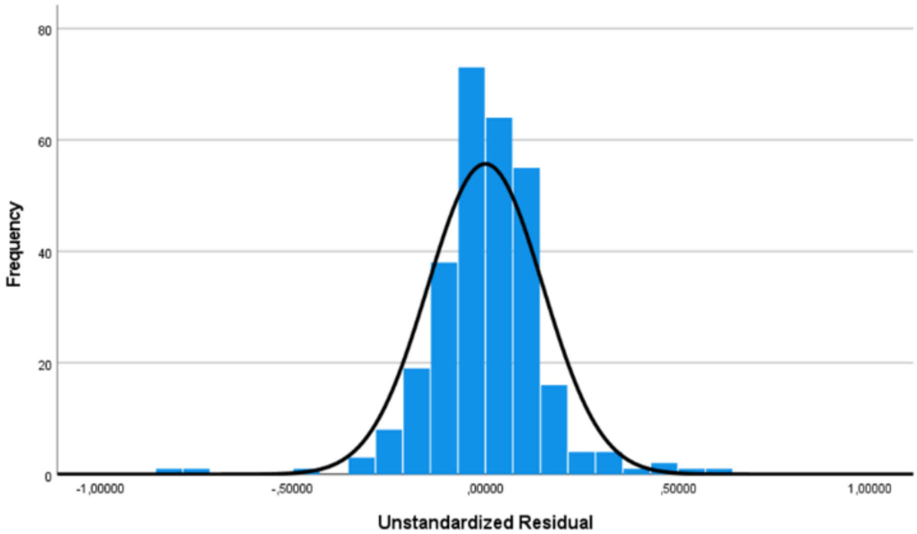
Distribution for studios (Pre-pandemic data, Helsinki-1)



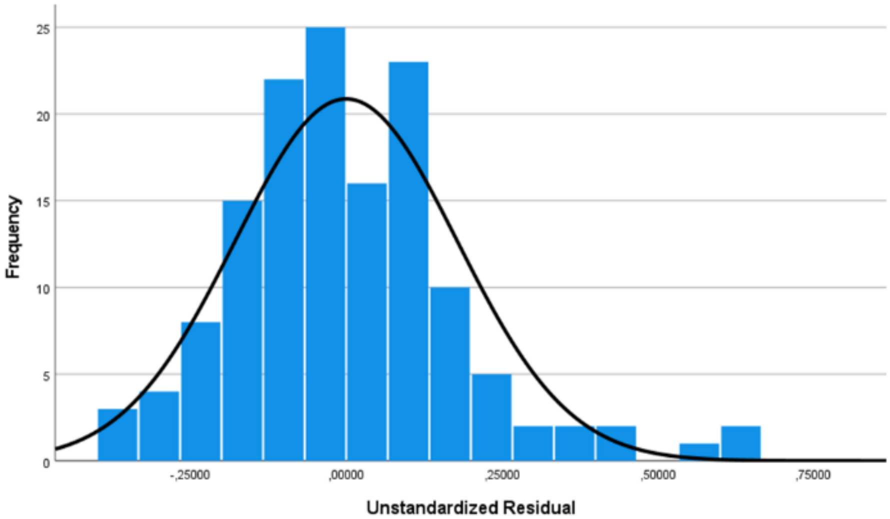
Distribution for two-room apartments (Pandemic data, Helsinki-1)



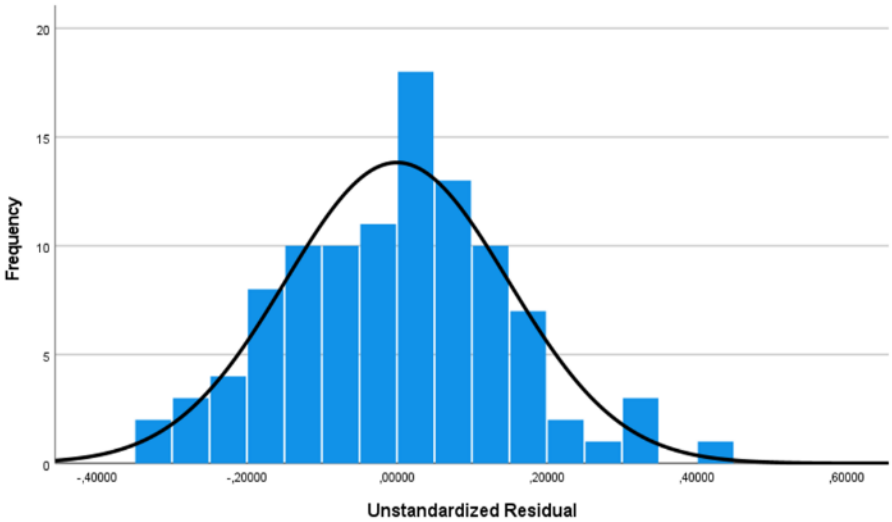
Distribution for two-room apartments (Pandemic data, Helsinki-2)



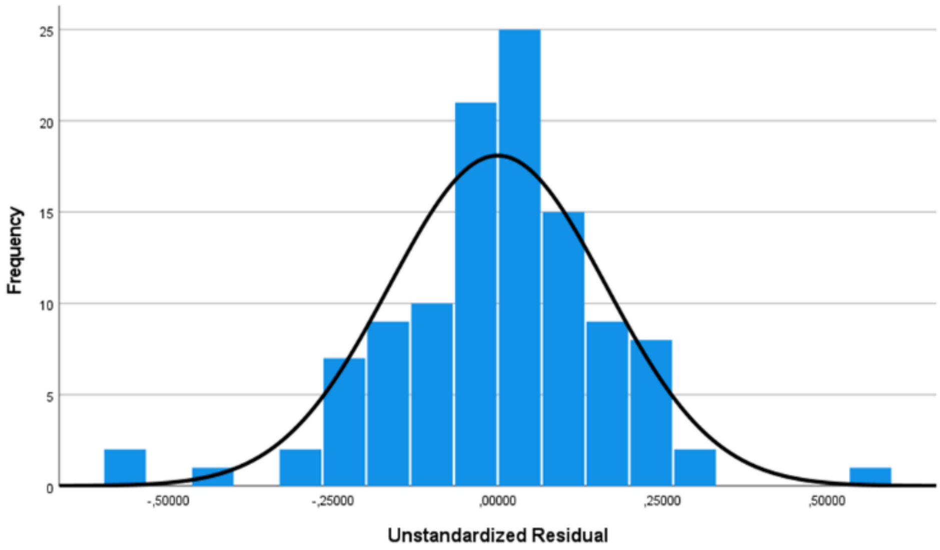
Distribution for three-room apartments (Pandemic data, Helsinki-1)



Distribution for apartments with more than three rooms (Pre-pandemic data, Helsinki-1)



Distribution for apartments with more than three rooms (Pre-pandemic data, Helsinki-2)



Distribution for apartments with more than three rooms (Pandemic data, Helsinki-1)